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A TECHNIQUE FOR MEASURING THE EXTERNAL NOISE OF A MOVING HELICOPTER

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A TECHNIQUE FOR MEASURING THE EXTERNAL NOISE

OF A MOVING HELICOPTER

INTRODUCTION

The noise produced by helicopters is of concern to the military for several reasons. Some of these are the hearing hazard presented to crew and passengers, the annoyance to the community around training areas, and perhaps most important, the loss of combat effectiveness caused by early enemy detection of aircraft activities.

In general, the problems involved in measuring the internal noise of helicopters are well known (2, 6 & 9) while annoyance is discussed in reference 3. The background of the detection problem has been covered extensively by several authors (Loewy, Ungar, etc.), and will not be repeated here.

For convenience, the topic of acoustic detection of an object may be arbitrarily divided into three broad areas: namely, the noise characteristics of the object, the medium through which the noise propagates, and the detector or listener that receives the noise. This report will deal mainly with the first area; that is, a determination of the noise characteristics of an object—in this case a moving helicopter.

While methods exist which may be used to predict detection distances (5, 11 & 13), these methods need accurate information concerning the sound source in order to be useful. Although considerable theoretical work (8, 11 & 12) is being done on methods of predicting the noise which will be produced by a given helicopter, there is very little published data dealing with actual measurements of moving helicopters. Most external noise measurements have been taken on either a hovering helicopter (7) showing maximum sound pressure level (SPL) recorded or the SPL versus time history of a fly-by with the helicopter a maximum of a few hundred feet from the measuring microphone. This report describes a method of collecting acoustic data from a moving helicopter to permit the generation of a polar plot of SPL versus angle in a vertical plane containing the flight path. This method may be used to compare SPLs produced by a variety of aircraft as well as to show the effects of any changes made in a particular aircraft. One factor which is inescapably a part of a measurement program of this type is the atmosphere and its effects on the acoustic signals being measured. This program makes no attempt to measure the acoustic characteristics of the atmosphere at the time of test but relies instead on published data. Ambient temperature and relative humidity were measured at the time of test and these variables were used to choose the appropriate acoustic characteristics (4). The computer programs used for data reduction are given in the appendixes.

METHOD

Our first attempt at recording a fly-over was at a quiet location at Aberdeen Proving Ground (APG) where the pilot was instructed to:

1. Fly as straight a path as possible over our microphones.

2. Maintain given altitude and airspeed.

3. Report by radio his passage over a nearby shoreline.

Since distance from the shoreline to our microphones was known and assuming a constant airspeed, the location of the aircraft could be calculated at any particular instant.

To check the accuracy of this location method, we decided to mark the instant that the helicopter was directly over the microphones. This was done by clicking a toy "cricket" noisemaker when the aircraft was subjectively determined to be directly over the microphone.

As a starting point, we requested an altitude of 500 feet and 90 knots indicated airspeed. As the experiment progressed and the runs were made at higher altitudes, several problems developed. The pilot reported that he was having difficulty lining up on the microphone site at the start of his run at a distance of two to three miles. At the lower altitudes, the pilot was able to sight on various features on the horizon such as tree lines, power line poles and other objects to maintain a straight line to our location. At the higher altitudes, these features dropped below the pilot's horizon and were thus unavailable for course guidance. The pilot also reported that he was having increasing difficulty in determining exactly when he was passing over the shoreline. As the data was being analyzed, it became obvious that there were fairly large errors in aircraft location. There was poor agreement between the time when the observer indicated that the aircraft was overhead and the time when calculations based on airspeed and distance from a reporting point (shoreline) showed that the aircraft should be overhead.

We decided to consider other methods of either aiding an observer in determining aircraft location or measuring aircraft location directly by automatic means. Several alternatives were discussed and discarded as not being suitable for our purposes. Personnel of the Velocity Measurement Unit, Materiel Testing Directorate, then suggested using a "skyscreen" to detect passage of the aircraft over a point.

A skyscreen is a photo-electric device so constructed that it detects objects passing through a sensitive area. Electronically, the skyscreen senses a change in light level reaching a photoelectric tube and produces a single electrical pulse whenever the change in light level exceeds a set value. The electrical circuitry is such that slow variations in light level do not produce an output. For this reason, clouds and changes in the angle of the sun have little or no effect on the operation of the skyscreen.

Preliminary trials showed that we could reliably detect aircraft passage at altitudes of several thousand feet. Above 3500 feet, detection became erratic, but since this was far in excess of the altitudes planned for acoustic measurements we did not investigate further to determine if the difficulty was caused by the skyscreen itself or if, in fact, the aircraft did not intercept the area covered by the skyscreen. It appeared that the latter was the more likely reason since at 3500 feet the width of the skyscreen's active area is only 350 feet. With the lack of visual references at this altitude a possible error of 175 feet on either side of a desired flight path was not unreasonable to expect.

The final configuration used during the acoustic tests is shown schematically in Figure 1 and pictorially in Figure 2. The details of the skyscreen system are given in Appendix A. In brief, the outputs of the skyscreens were used to start and stop electronic counters. The counters were used as accurate interval timers so that they gave a precise indication of the time that elapsed between a start and a stop pulse. Switches were used to interchange the pulses from the skyscreens so that the aircraft could make runs in both directions. For example, during a run from left to right, SS3 would be used to start the counter used to measure velocity and SS4 would be used to stop this

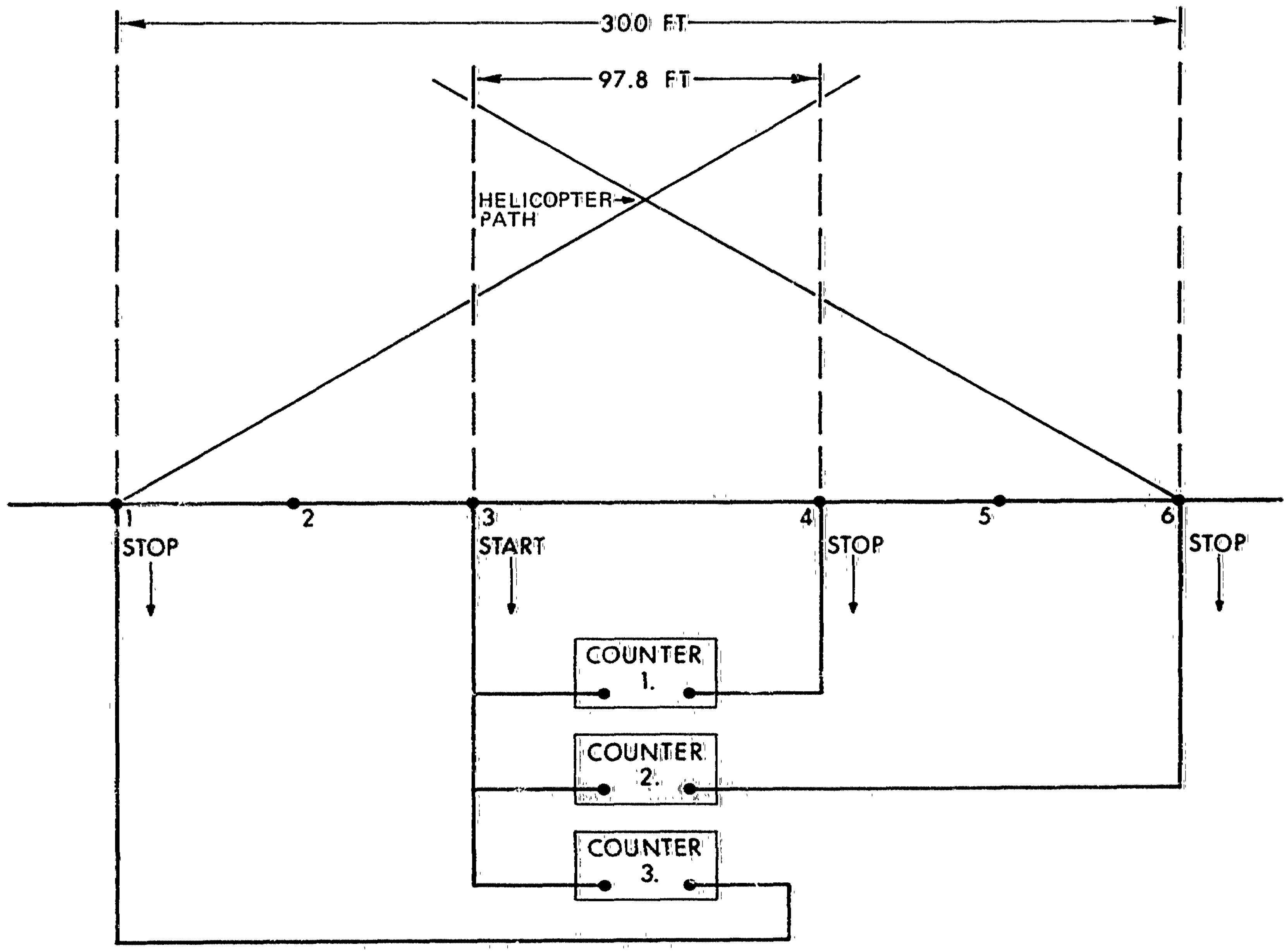

Fig. 1. Schematic of sky-screen system.

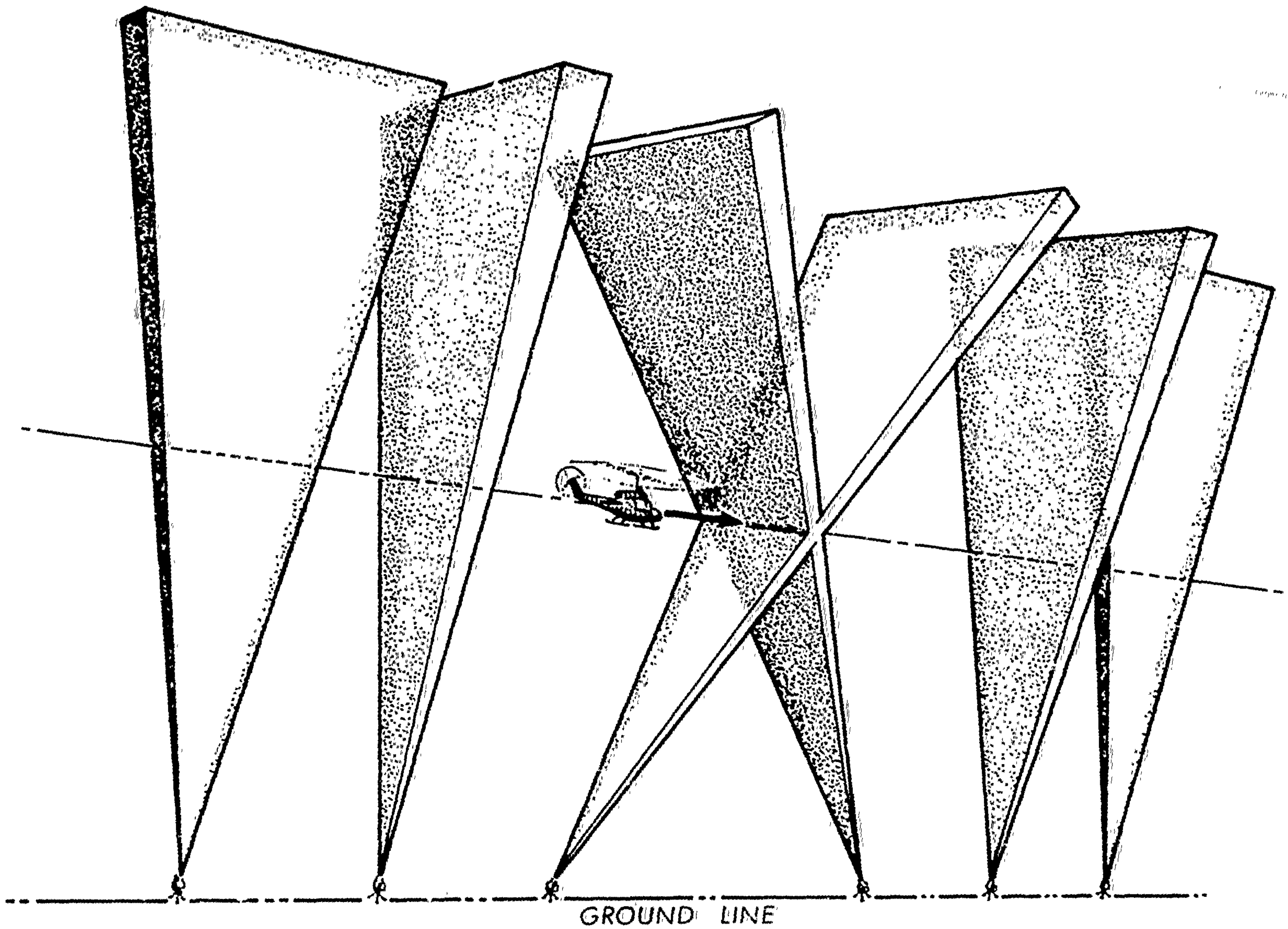

Fig. 2. Sky-screen system used during acoustic tests.

counter. During a run from right to left, however, SS4 would apply the start pulse and SS3 would apply the stop pulse. Skyscreens 1 and 6 were tilted off the vertical by the amount necessary to cause their sensitive areas to converge at the nominal altitude chosen for the flights. By counters 2 and 3, it was possible to measure the height of the aircraft above the microphones. Skyscreens 2 and 5 were aligned so that their sensitive areas were along the flight path rather than at right angles to it. If these two skyscreens detected the aircraft, we knew that the aircraft was on a path within the rotor radius of being directly over the microphone.

Acoustic Data Collection

A block diagram of the equipment used to record the aircraft flyovers is shown in Figure 3. A calibration signal produced by a Bruel & Kjaer (B&K) Type 4220 pistonphone was recorded on the tapes and served as the reference level during playback.

We found during our preliminary studies that applying a tone, or click, as a marker on the tape at the instant the aircraft was overhead was not very satisfactory. During an octave band analysis of the tapes, there were, of course, octave bands which did not pass the tone and consequently there was no marker on the record of those particular octave bands. Rather than attempting to generate a broadband noise for use as a marker, we decided to try a different approach. A circuit was constructed that applied a momentary short circuit across the input of the tape recorder when a pulse from SS3 indicated that the aircraft was directly over the microphone. In this manner, we were able to get a distinct marker that was independent of frequency and showed clearly on all the analyses.

The test site for the acoustic measurements was an abandoned airfield at APG. The equipment was located at the extreme northern end of the north-south runway. The runway gave the pilot a good visual reference for maintaining a straight flight path over the microphones. A total of 12 runs was recorded. Runs 1 to 6 were at a nominal 300 feet altitude and runs 7 to 12 were at 600 feet. The direction of the runs alternated so that the odd numbers were in the north to south direction while the even numbers were from south to north. Aircraft speed and height for the first seven flights are given in Table 1.

The terrain in the test area was flat and there were no obstructions along the flight path. The ground surface consisted of the broken-up remains of the old asphalt runway and the surrounding area was covered with low grass.

The flights took place in the early morning hours to take advantage of low wind conditions. Surface winds were two miles per hour or less from the north for the first eight runs after which they shifted to the south at three miles per hour or less. The temperature rose from $28^{o}F$ to $34^{o}F$ during the test period while relative humidity varied from 78 percent to 63 percent.

The microphone used was a B&K ½" condenser microphone, Model 4134. The microphone was oriented so that the diaphragm lay in a vertical plane which also contained the flight path. When the microphone was oriented in this manner, sound waves from the aircraft always hit the microphone at 90^{o} incidence, thus eliminating possible problems with directional characteristics of the microphone.

TABLE 1

Aircraft[a] Flight Data

Flight Number	True Air Speed (Knots)	Height Above Microphone (Feet)
1	78	241
2	59	271
3	77	238
4	65	271
5	77	272
6	65	305
7	76	526

[a]The aircraft was a UH-1H SN 7059234.

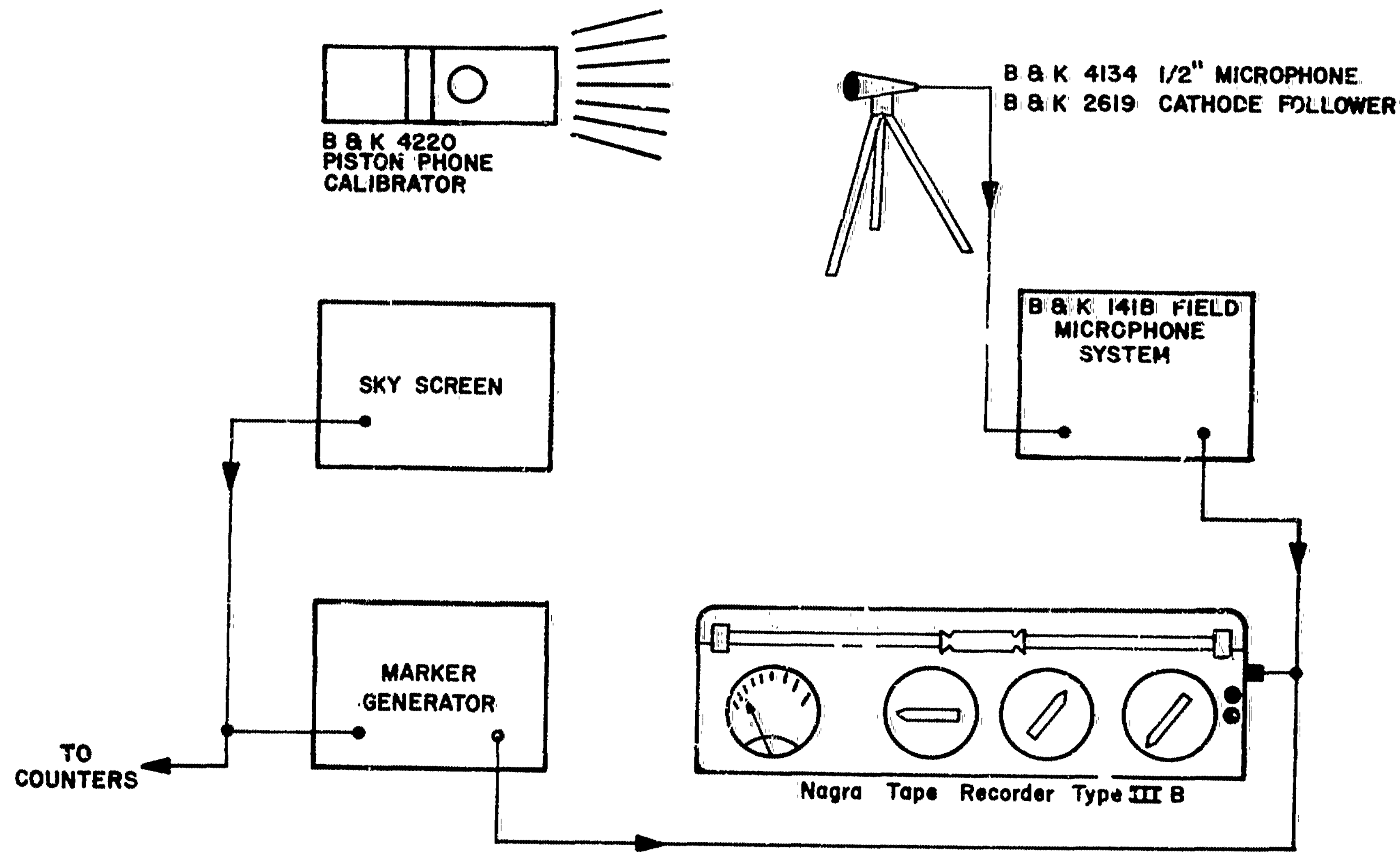

Fig. 3. Equipment used to record the noise of aircraft flyovers.

Data Reduction

The data reduction portion of the test program was broken into several phases as follows:

1. Determination of aircraft location in time and space.

2. Analysis of acoustic data into a sound pressure level (SPL) versus time history for each octave band.

3. Combination of aircraft location data and acoustic data into a plot of the SPL around the aircraft.

Determination of Aircraft Location

As the aircraft passed over the skyscreen equipment we obtained measurements of several variables; (1) the precise instant at which the aircraft passed over the microphone, (2) the aircraft speed, and (3) the height of the aircraft above the microphone. If we assumed that aircraft speed and height did not vary significantly during a run, it was possible to determine the aircraft location at any time during the run. For example, referring to Figure 4, if given a height, (H), and speed, (V), the aircraft location, (L), at a time, (t), before the aircraft passes directly overhead is given by:

$$D = Vt$$

$$\emptyset = \tan^{-1}\frac{H}{D}$$

$$S = \sqrt{D^2 + H^2}$$

However, since the speed of sound is finite, the sound received at the microphone when the aircraft is at location L was actually emitted when the aircraft was at location L'. Again, referring to Figure 4, the location of L' may be determined from:

$$S' = \frac{-(2S\frac{V}{C}\cos\alpha) + \sqrt{\left(2S\frac{V}{C}\cos\alpha\right)^2 - 4\left(1-\left(\frac{V^2}{C}\right)\right)(-S^2)}}{2\left(1-\left(\frac{V}{C}\right)^2\right)}$$

where S = slant distance to actual location

S' = slant distance to sound location

V = speed of aircraft

C = speed of sound in air

Since it was necessary to calculate many data points in order to generate a plot of the sound field around the aircraft, we decided to investigate the possibility of using a computer to ease the computational workload. The result was a FORTRAN language program which performed the

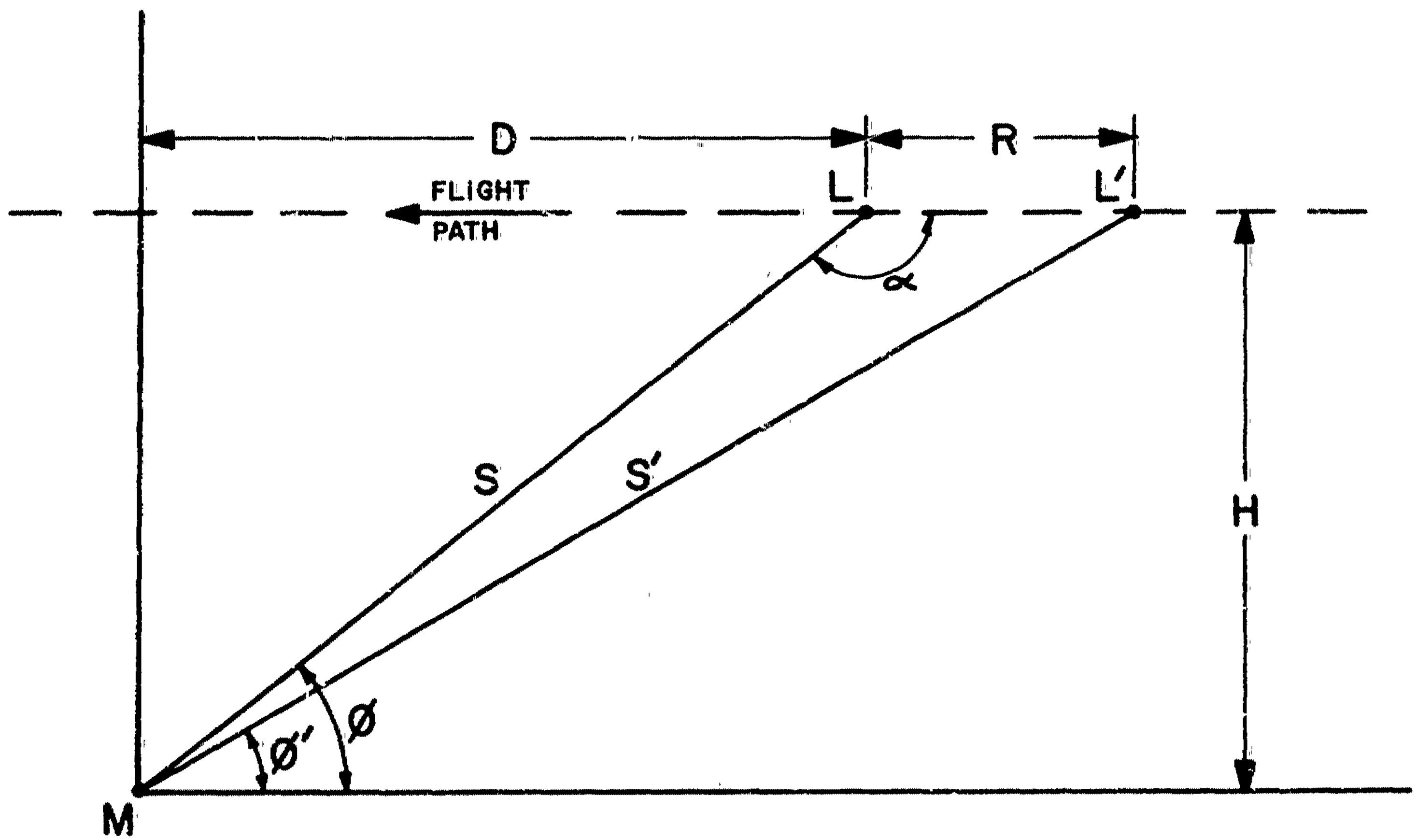

Fig. 4. Determination of actual and sound location of a helicopter in flight.

functions diagrammed in Figure 5. The operation of the program is fully described in Appendix B. The program used inputs of ambient temperature, aircraft speed and height and an arbitrary starting point to give as output a series of times, angles and slant ranges which define the aircraft's true location and sound location in time and space. An example of the computer output is shown in Table 2.

Analysis of Acoustic Data

The tape recordings were played back using the equipment set-up shown in Figure 6. The calibration tone produced by the pistonphone and recorded on all tapes was used to set all reference levels in the analysis equipment. Each flight was played back through each octave band filter from 63 Hz to 8000 Hz. The results were a series of octave band pressure level versus time histories for each flight.

Combination of Aircraft Data and Acoustic Data

The final phase of the data reduction process consisted of correlating the location data with the acoustic data and generating a plot of SPL versus angle around the aircraft. The SPL data were read from the time histories at the times indicated in the location data. The marker placed on the tapes as the aircraft passed overhead was reproduced on the SPL time histories and this marker was used as a time reference. An example of the resulting table of SPLs for each octave band is shown in Table 3. Although these SPLs could be directly plotted on polar paper, the usefulness of such a presentation is somewhat limited since each data point was measured at a different distance from the aircraft. We therefore decided to correct each data point to a constant distance from the source and we arbitrarily chose 200 feet. In other words, the data presented in the polar plots represents the SPL that would be measured in a vertical plane containing the flight path, by a microphone located at a constant 200 foot distance from the aircraft and at various angles around the aircraft.

The SPL data was corrected to a constant distance by the well known relation (14):

$$SPL_{200} = SPL_D + 20 \log \frac{D}{200} + \alpha (D-200)$$

where

SPL_{200} = sound pressure level at 200 feet

SPL_D = sound pressure level measured at distance D

α = atmospheric attenuation factor.

The α used for the calculations was obtained from reference 4 using the temperature and humidities recorded during the flights. Table 4 shows the values used.

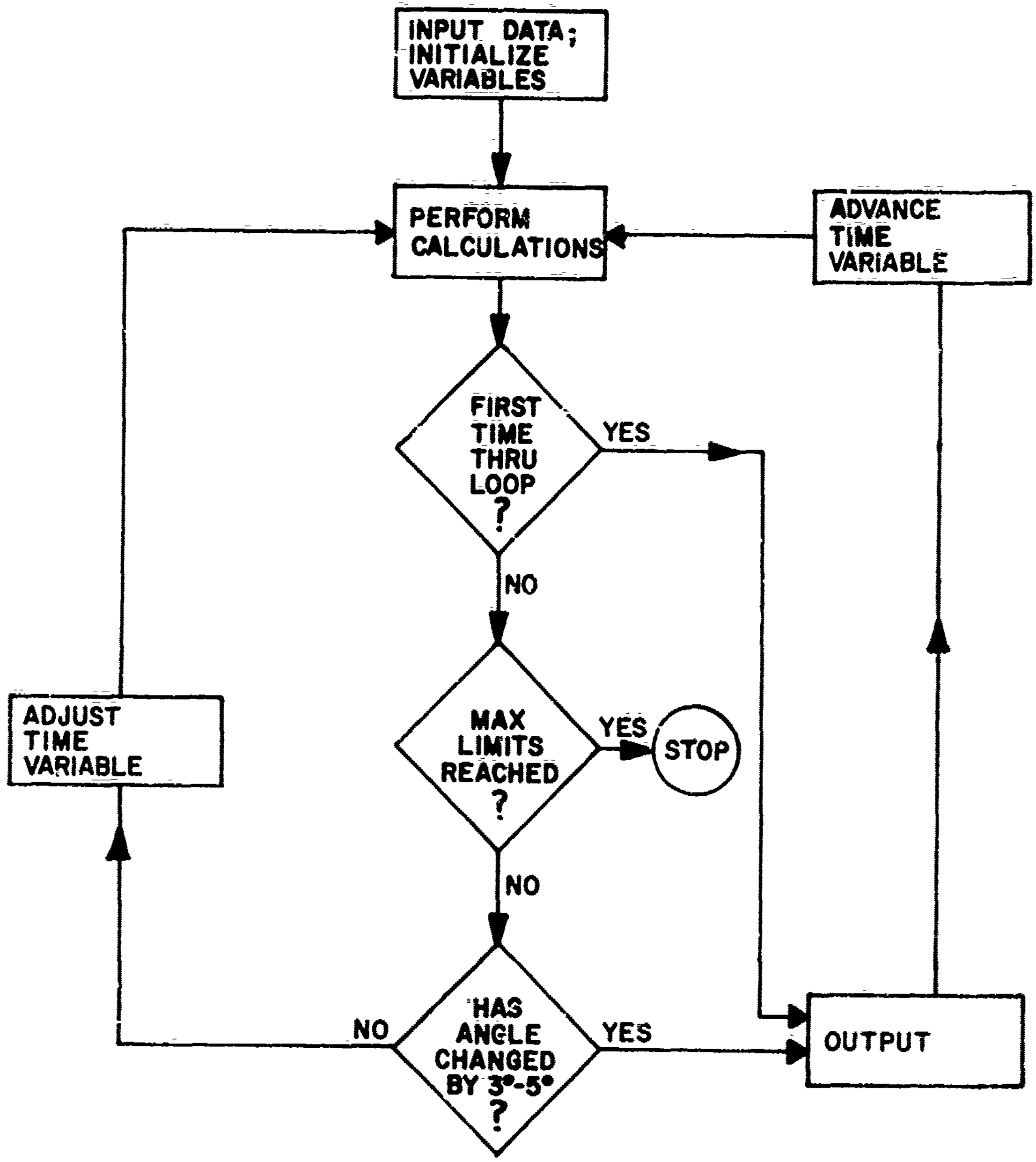

Fig. 5. Flow chart of computer program used to calculate helicopter location.

TABLE 2

Example of Computer Output for Helicopter-Location Program

DATA POINT N	TIME FROM START, SEC	VISUAL LOCATION ANGLE, DEGREES	VISUAL SLANT RANGE, FEET	SOUND LOCATION ANGLE, DEGREES	SOUND SLANT RANGE, FEET
1	0.0	1.9	7443.9	1.6	8406.1
2	39.0	5.7	2615.2	4.7	2951.9
3	47.5	8.9	1568.7	7.8	1769.2
4	51.5	12.9	1081.3	11.4	1217.6
5	53.5	16.7	841.4	14.8	945.6
6	55.0	21.3	665.3	18.9	745.5
7	56.0	26.0	551.6	23.1	615.8
8	56.8	31.3	464.5	27.9	515.8
9	57.3	35.8	412.0	32.0	456.1
10	57.7	40.2	373.6	36.0	410.7
11	58.1	45.7	337.3	41.0	368.0
12	58.4	50.6	312.5	45.5	338.4
13	58.6	54.3	297.3	48.9	320.1
14	58.8	58.4	283.6	52.8	303.2
15	59.0	62.8	271.4	57.0	288.0
16	59.2	67.7	261.0	61.6	274.5
17	59.3	70.2	256.5	64.0	268.5
18	59.4	72.9	252.6	66.6	263.1
19	59.5	75.6	249.2	69.2	258.2
20	59.6	78.4	246.4	71.9	253.9
21	59.7	81.2	244.2	74.7	250.2
22	59.8	84.1	242.7	77.6	247.2
23	59.9	87.1	241.7	80.5	244.8
24	60.0	90.0	241.4	83.4	243.0
25	60.1	92.9	241.7	86.4	241.9
26	60.2	95.9	242.7	89.3	241.4
27	60.3	98.8	244.2	92.3	241.6
28	60.4	101.6	246.4	95.2	242.4
29	60.5	104.4	249.2	98.0	243.8
30	60.6	107.1	252.6	100.8	245.8
31	60.7	109.8	256.5	103.6	248.4
32	60.8	112.3	261.0	106.3	251.5
33	60.9	114.8	265.9	108.8	255.1
34	61.1	119.5	277.3	113.7	263.7
35	61.3	123.7	290.3	118.3	274.1
36	61.5	127.6	304.7	122.4	285.9
37	61.7	131.1	320.5	126.2	299.1
38	61.9	134.3	337.3	129.6	313.3
39	62.2	138.5	364.3	134.1	336.4
40	62.5	142.1	392.9	138.1	361.2
41	62.9	146.1	433.1	142.5	396.2
42	63.4	150.2	485.8	146.9	442.6
43	63.9	153.5	540.5	150.5	490.9
44	64.8	157.9	642.3	155.5	581.2
45	65.8	161.4	755.6	159.4	684.7
46	67.3	165.1	936.8	163.4	843.8
47	69.3	168.2	1178.2	166.8	1059.7
48	72.3	171.0	1544.2	170.0	1387.5
49	77.0	173.8	2220.5	173.0	1993.6
50	91.8	176.5	3350.6	176.1	3545.4

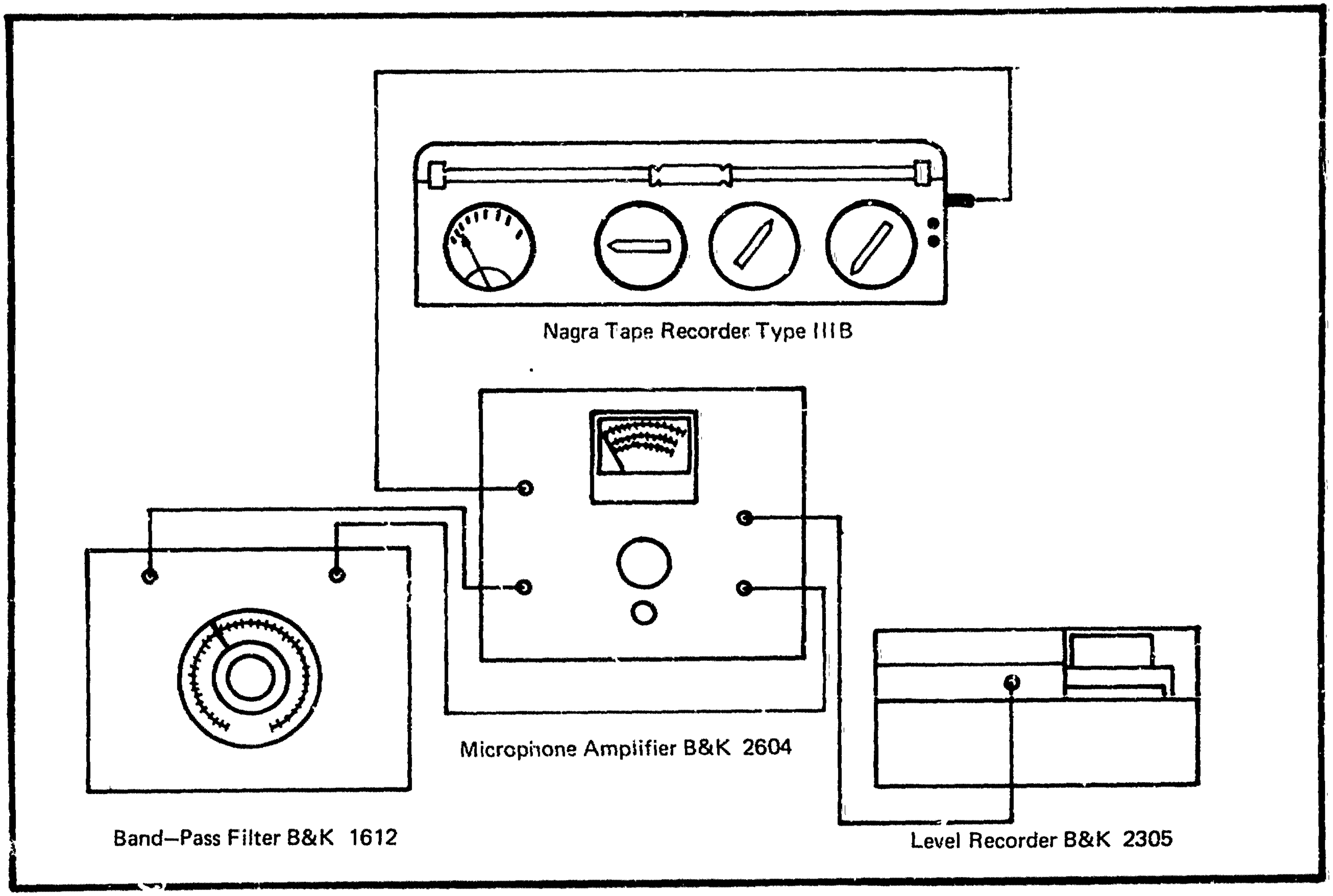

Fig. 6. Diagram of equipment used for acoustic data analysis.

TABLE 3

Example of Combined Location and Sound Pressure Level Data

DATA POINT N	TIME FROM START, SEC	ACTUAL ANGLE, DEGREES	ACTUAL RANGE, FEET	SOUND LOCATION ANGLE, DEGREES	SOUND SLANT RANGE, FEET	OCTAVE BAND SOUND PRESSURE LEVELS, OCTAVE BAND CENTER FREQUENCY, Hz: 63	125	250	500	1K	2K	4K	8K
1	0.0	1.2	[illegible]	1.5	2906.1	77	-	-	-	-	-	-	-
2	39.0	5.3	2615.2	4.7	[illegible]	84	[illegible]	79	68	61	-	-	-
3	47.5	8.9	1564.7	7.3	[illegible]	93	91	81	74	63	53	-	-
4	51.9	12.4	1081.3	11.4	1217.6	96	94	92	80	67	61	52	-
5	53.9	16.7	841.4	14.8	945.6	97	96	94	83	74	63	55	-
6	55.0	21.3	665.2	18.9	745.5	97	91	88	86	74	65	57	-
7	56.0	26.0	551.6	23.1	615.8	96	89	89	83	74	65	59	-
8	56.8	31.2	464.5	27.9	515.8	[illegible]	85	88	85	74	67	62	54
9	57.3	35.8	412.8	32.0	456.1	94	82	88	86	75	68	64	55
10	57.7	40.2	373.6	36.0	410.7	93	93	89	89	78	70	65	57
11	58.1	45.7	337.3	41.6	368.0	90	86	91	89	79	72	67	59
12	58.4	50.6	312.5	45.5	338.4	89	88	92	89	78	75	69	61
13	58.6	54.3	297.3	48.9	320.1	87	90	92	88	78	75	69	61
14	58.8	58.4	283.6	52.8	303.2	85	92	92	87	80	76	70	63
15	59.0	62.8	271.9	57.0	288.6	85	92	92	86	80	76	71	65
16	59.2	67.7	261.0	61.6	274.5	84	92	91	85	80	76	71	66
17	59.3	70.2	256.5	64.0	268.5	82	92	91	85	80	76	72	66
18	59.4	72.9	252.6	66.6	263.1	81	92	91	86	80	77	72	66
19	59.5	75.6	249.2	69.2	258.2	82	92	90	86	80	77	72	66
20	59.6	78.4	246.4	71.9	253.9	81	92	90	86	81	77	72	67
21	59.7	81.2	244.2	74.7	250.2	81	92	90	86	82	78	73	68
22	59.8	84.1	242.7	77.6	247.2	81	92	89	86	83	78	74	68
23	59.9	87.1	241.7	80.5	244.8	81	91	89	86	82	79	74	68
24	60.0	90.0	241.4	83.4	243.0	80	91	88	86	82	79	74	68
25	60.1	92.9	241.7	86.4	241.9	79	90	88	86	82	79	74	68
26	60.2	95.9	242.7	89.3	241.4	79	90	87	86	82	79	74	68
27	60.3	98.8	244.2	92.3	241.6	79	90	87	86	82	79	74	68
28	60.4	101.6	246.4	95.2	242.4	79	90	86	86	82	79	74	68
29	60.5	104.4	249.2	98.0	243.8	79	90	86	85	82	79	74	68
30	60.6	107.1	252.6	100.8	245.8	79	89	86	85	82	79	74	68
31	60.7	109.8	256.5	103.6	248.4	79	89	85	85	82	79	74	68
32	60.8	112.3	261.0	106.3	251.5	79	88	85	84	82	79	74	68
33	60.9	114.8	265.9	108.8	255.1	79	88	84	84	81	79	74	68
34	61.1	119.5	277.3	113.7	263.7	78	87	83	82	81	79	73	68
35	61.3	123.7	290.4	118.3	274.1	78	88	82	82	81	78	73	68
36	61.5	127.6	304.7	122.4	285.9	78	86	81	82	81	77	72	68
37	61.7	131.1	320.5	126.2	299.1	77	86	79	82	80	76	71	67
38	61.9	134.3	[illegible]	[illegible]	313.3	79	86	79	82	79	75	71	67
39	62.2	[illegible]	364.5	139.1	[illegible]	80	85	79	81	78	75	70	66
40	62.5	[illegible]	392.9	[illegible]	[illegible]	80	85	80	80	78	75	69	65
41	62.9	146.1	433.1	[illegible]	[illegible]	80	83	82	78	76	73	67	62
42	63.4	[illegible]	[illegible]	[illegible]	[illegible]	80	80	82	78	72	72	66	60
43	63.9	[illegible]	[illegible]	153.5	490.9	80	[illegible]	81	77	73	68	63	56
44	64.8	[illegible]	632.3	155.5	[illegible]	80	74	78	72	[illegible]	67	60	54
45	65.8	[illegible]	[illegible]	158.4	[illegible]	80	73	73	72	70	65	57	-
46	67.7	[illegible]	[illegible]	161.4	843.8	79	74	71	71	66	62	54	-
47	69.3	[illegible]	[illegible]	166.8	1059.7	78	76	66	71	66	60	51	-
48	72.3	[illegible]	1594.2	170.0	1387.5	78	73	66	65	62	55	-	-
49	77.8	[illegible]	[illegible]	[illegible]	[illegible]	76	70	[illegible]	52	[illegible]	-	-	-
50	91.3	176.5	[illegible]	176.1	[illegible]	68	-	-	-	-	-	-	-

TABLE 4

Atmospheric Attenuation Factors, α, for Each Octave Band Used in Calculating Sound Pressure Levels at 200 Feet

Flight Number	α, in dB/1000 Feet in the Indicated Octave Bands							
	63	125	250	500	1000	2000	4000	8000
1	0.1	0.1	0.3	0.6	1.8	5.4	15.5	26.9
2	0.1	0.1	0.3	0.7	1.9	5.6	16.0	27.8
3	0.1	0.1	0.3	0.7	2.0	6.0	16.7	29.2
4	0.1	0.1	0.3	0.7	2.1	6.0	16.9	29.6
5	0.1	0.1	0.3	0.7	2.0	6.0	16.7	29.1
6	0.1	0.1	0.3	0.7	2.0	5.9	16.6	28.8
7	0.1	0.1	0.3	0.7	2.0	5.9	16.6	28.8

DISCUSSION

Skyscreen

The skyscreen system performed well in locating the helicopter in space and indicated the instant that the helicopter was directly over the microphones. This system had several advantages over other methods of locating the helicopter. Some of the advantages were:

1. The system was portable and could be emplaced at any desired location. This contrasted with a radar system which was usually fixed and therefore limited the test area to the vicinity of the radar set. A mobile radar set could be used, of course, but the cost of such a system would be far in excess of the skyscreens.

2. The operator was removed from the system. This eliminated problems of reaction time and subjective judgments of helicopter location.

3. The system provided an immediate readout. This would not be the case with, for example, a system that used photographic means to measure helicopter location.

A disadvantage of the skyscreen system was that it required 110VAC power for operation. However, since the power requirements are fairly low, it is possible to operate at a remote site by powering the system from a small acoustically treated engine generator set or a DC-AC inverter. This gives complete freedom in site selection since all of the acoustic equipment can be battery operated.

Acoustic Data Reduction

The analysis of acoustic data from a moving source had several opposing requirements. For example, since the sound pressure was changing with time, one requirement of the measuring system was that the level indicator have a response time fast enough to follow the changes in level. A fast response time, however, was directly contradictory to another requirement; namely, that the measuring system have a long averaging time in order to accurately measure the random components of the noise. Since the averaging time necessary for a given accuracy decreased as the bandwidth of the analysis system increased, we used the standard octave band filters from 63 Hz to 8000 Hz so that we could use a short averaging time and still have reasonable confidence in the accuracy of the measurements. A further inducement to use full octave bands, at least for this program, was the sheer number of data points which had to be read. For example, for one flight there were about 400 data points. Analysis by 1/3 octave bands would increase this to 1200 points. Since we had to manually read the data points, we felt the additional time required was not justified at this time. However, if suitable equipment becomes available to shorten the time required to read the data, it will be a simple matter to replay the tapes for analysis as desired.

Computer Programs

The effort to lighten the computational requirements by using computer programs worked very well. As mentioned earlier, the only phase of the data reduction process that was not automated was the reading of SPL levels at the appropriate times on the SPL versus time records.

Once the SPL data was put on punched paper tape, all other operations, from the calculations of helicopter location to the final plots, were carried out automatically.

Atmospheric and Terrain Effects

As pointed out in the Method Section, no attempt was made to measure the acoustic characteristics of the atmosphere at the time of the test. However, it should be possible to use data from flights at two different altitudes to actually calculate atmospheric losses. For instance, if one flight was twice the height of another, the levels when the aircraft was directly overhead should differ by 6 dB ($20 \log \frac{D1}{D2}$) plus an amount that depended on the frequency of the signal and the atmospheric losses. Of course this only applies if we assume that the source levels were identical for each flight; or we could possibly apply a correction for a different source level. One way to do this is to examine the differences in the lowest frequency band where atmospheric losses are very small. Then we could assume that any difference in the levels not attributed to the factor $20 \log \frac{D1}{D2}$ was caused by a difference in the source level. We could also use the same method to calculate losses at angles other than 90°.

The effect that the terrain has on sound propagation from a helicopter is not very well known. However, there is general agreement that terrain effects are small at angles of greater than 7° (2) to 10° (15). The primary problem in defining terrain effects lies mainly in the nearly infinite variation in terrain features from place to place. Data is available that may be used for particular terrain, such as grassland and jungle (2). Since our test site did not fit the available data we did not calculate SPLs at angles less than 10° or greater than 170°. Since present tactics provide that many missions will be flown at "tree-top" or "nap of the earth" levels where angles will be less than 10°, this presents a serious omission for operational purposes and further work should be done in defining terrain effects. We do, however, report the measured SPLs at all angles for which we have data. Examination of the tables shows that at some of the higher frequencies data is not reported at angles less than 20° - 30°. This occurs for several reasons: (1) the source level is relatively low at high frequencies; (2) high frequencies are rapidly attenuated by the atmosphere; and (3) the dynamic range of the recording system limits the minimum signal level which may be recorded.

Applications

The methods given in this report may be used (1) to gather accurate data which may then be compared to data predicted from theories of helicopter noise generation, (2) to standardize data collection and reporting so that various types of helicopters may be directly compared, (3) as a basis for a prediction of detection distance if given detection level criteria, and (4) possibly as a means for measuring atmospheric attenuation of acoustic signals.

RESULTS

Although a total of 12 flights were recorded, only the first six were completely satisfactory. On these six flights, we were able to measure the speed, altitude and proper path of the helicopter. It tripped both skyscreens (2 and 5 in Fig. 1) which were used to indicate that the aircraft was on the desired path over the microphone. On the remainder of the flights, while we were able to collect good acoustic, speed and altitude data, we did not get an indication that the helicopter was on the proper path. Since the weather became rapidly unsatisfactory after run 12, we were forced to stop collecting data before resolving the problem. In spite of the fact that flight 7 was off line we decided to include the data simply for comparison with the lower altitude flights but, since more than 400 data points must be read for each flight, we did not read the data for flights 8 through 12.

The sound pressure levels, as measured in each octave band, are given in Appendix C along with the corresponding location data. The sound pressure levels, as calculated for a constant distance of 200 feet, along with their corresponding angles, are given in Appendix D. The polar plots of SPL vs angle by octave bands for one flight are shown in Figures 9 thru 16. All flights are shown in Appendix E.

Examination of the polar plots showed that the first two octave bands (63 Hz and 125 Hz) were stongly directional with a difference of approximately 30 dB between the maximum and minimum SPL. An interesting feature of the 125 Hz plots was the "notch," or drop, in SPL in the 30° to 50° region. This notch seemed to be somewhat speed dependent since for flights 1, 3, and 5, which had speeds of 124, 131, and 129 feet per second respectively, the notch occurred at about 35°. The speed for flights 2, 4, and 6 was in the area of 99-110 feet per second and the notch shifts to the 45° - 50° region.

The rest of the octave bands showed less and less directivity until at 1000 Hz and above, the SPLs showed little change with direction.

CONCLUSIONS

1. The method presented is capable of providing accurate SPL measurements of a moving helicopter.

2. Data collected in this manner could be used to directly compare different helicopters.

3. Theories of helicopter noise generation may be checked by this method of data collection.

4. Present understanding of terrain effects is not sufficient to permit accurate estimates of propagation at angles of less than 10°.

RECOMMENDATIONS

It is recommended that:

1. Further work be done to gather data and devise methods of predicting terrain effects.

2. This method, with modifications if necessary, be used as a standardized method of measuring helicopters in flight.

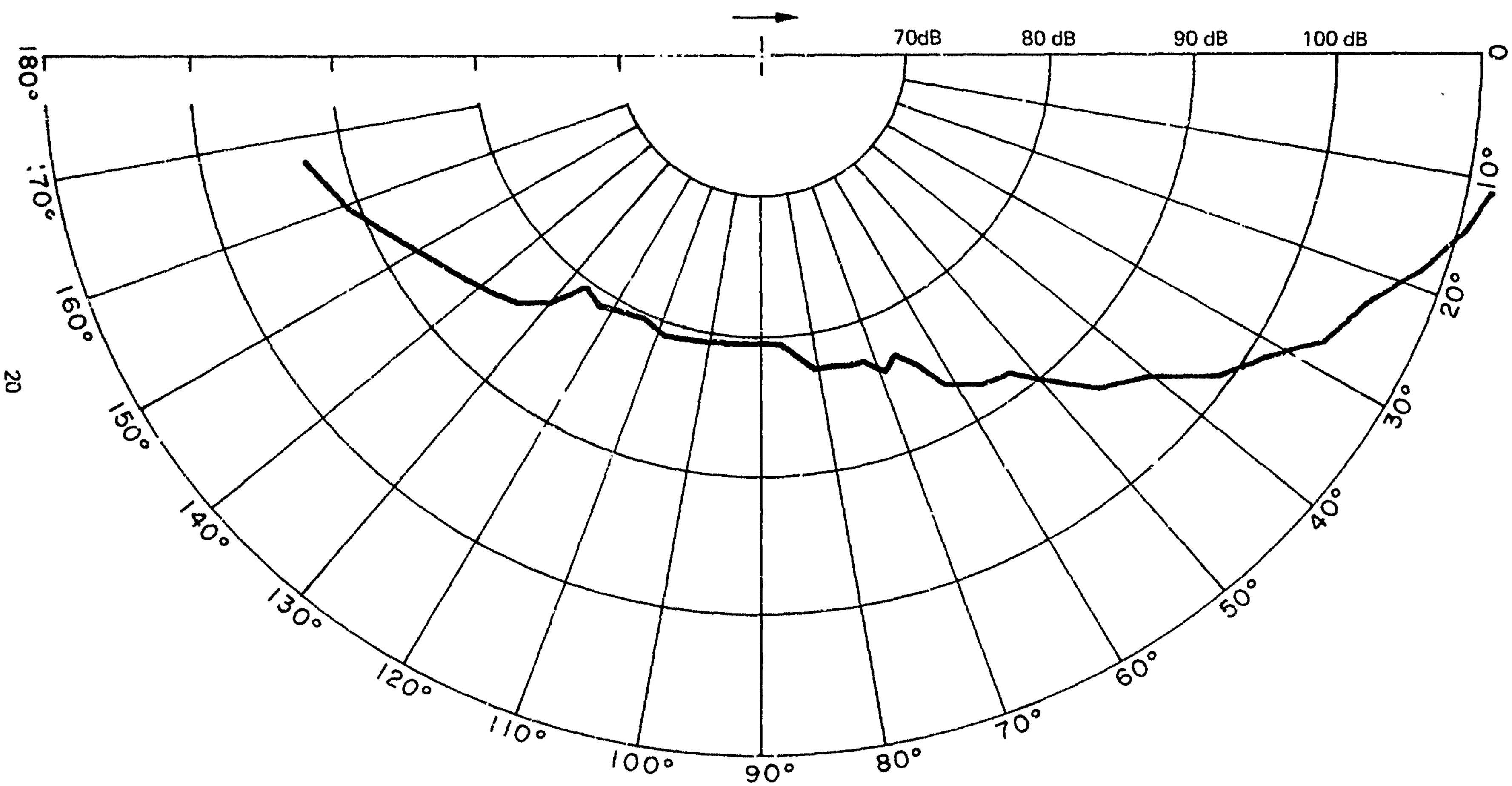

Fig. 7. Sound pressure level in the 63 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

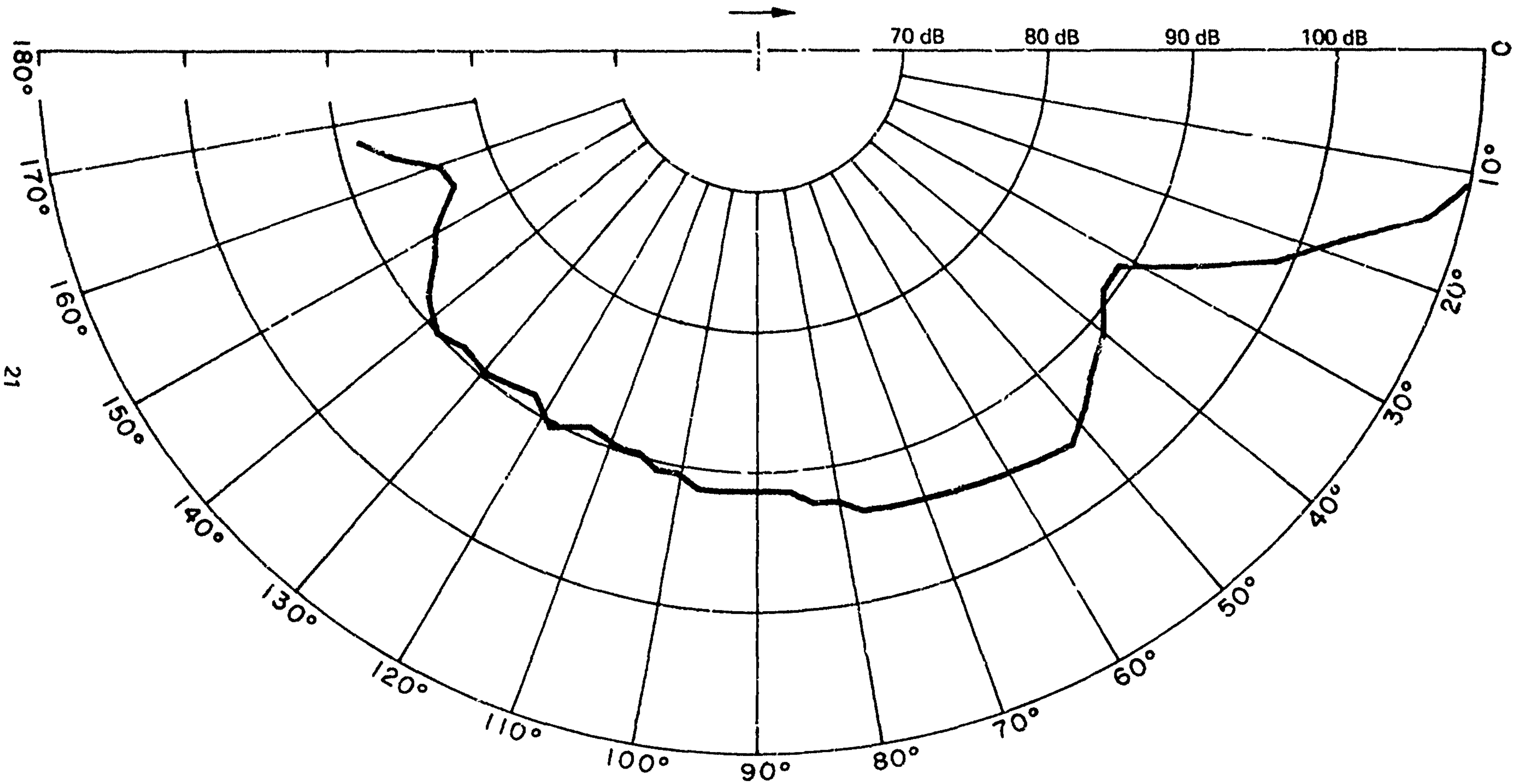

Fig. 8. Sound pressure level in the 125 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

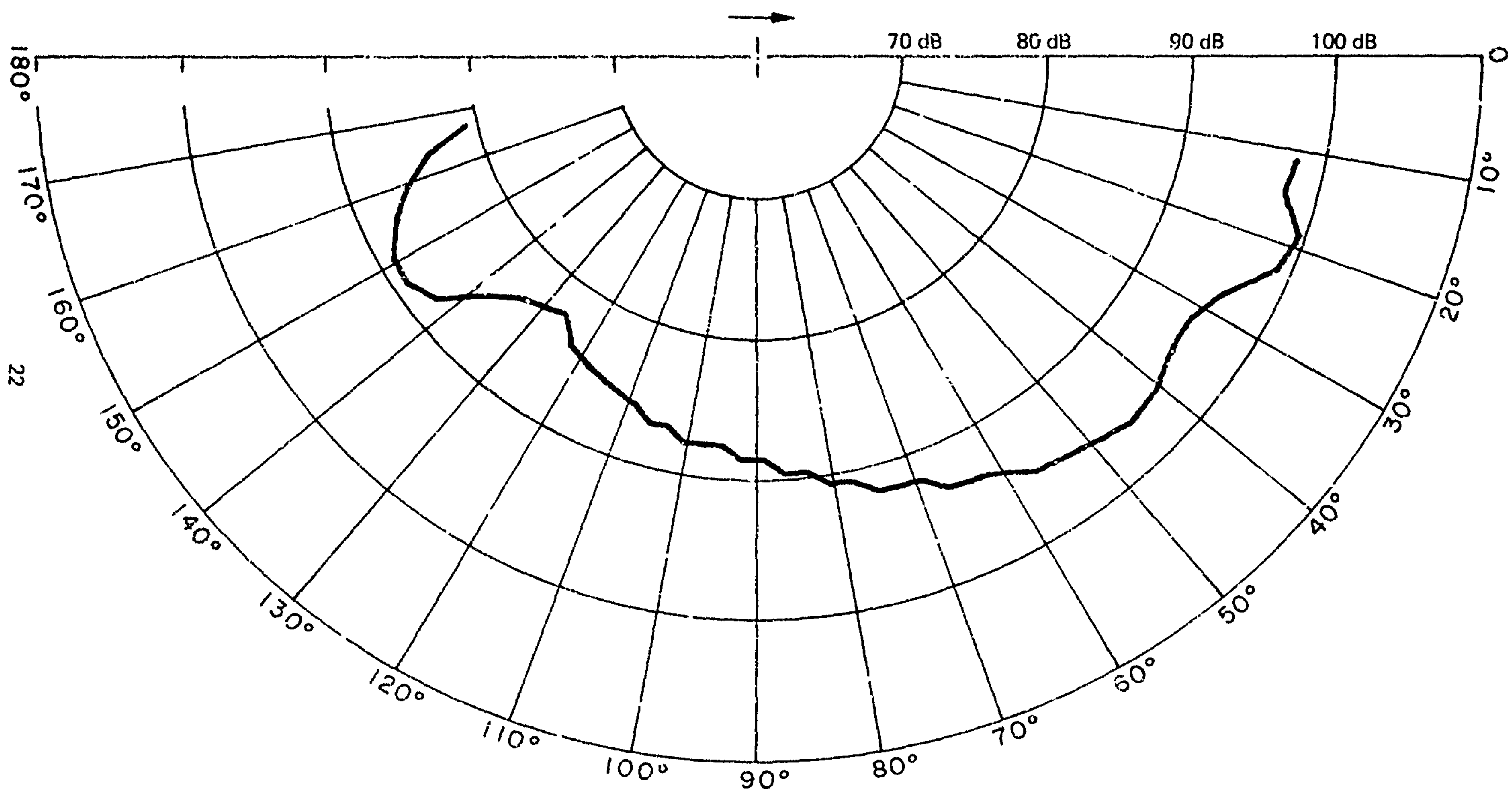

Fig 9. Sound pressure level in the 250 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

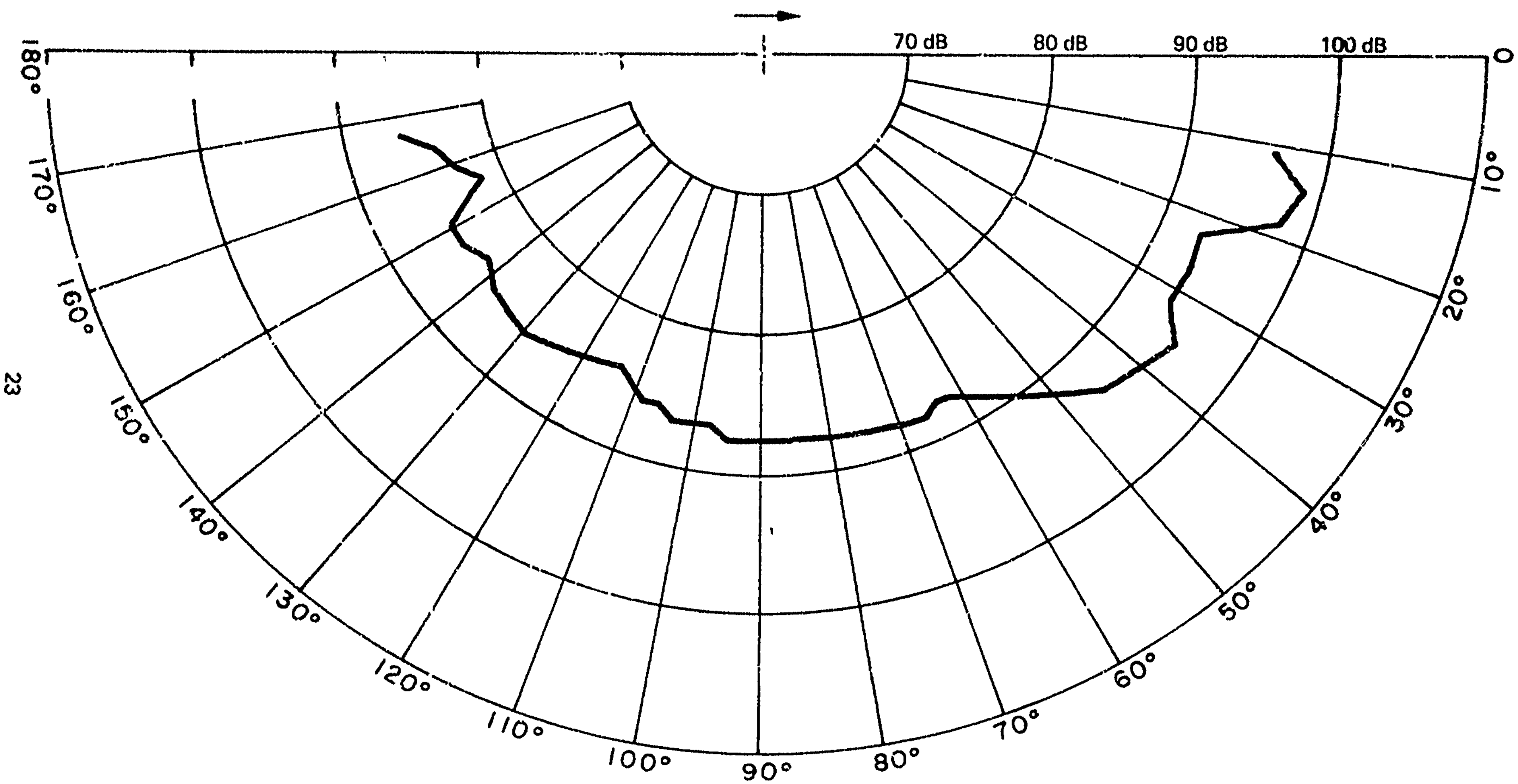

Fig. 10. Sound pressure level in the 500 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

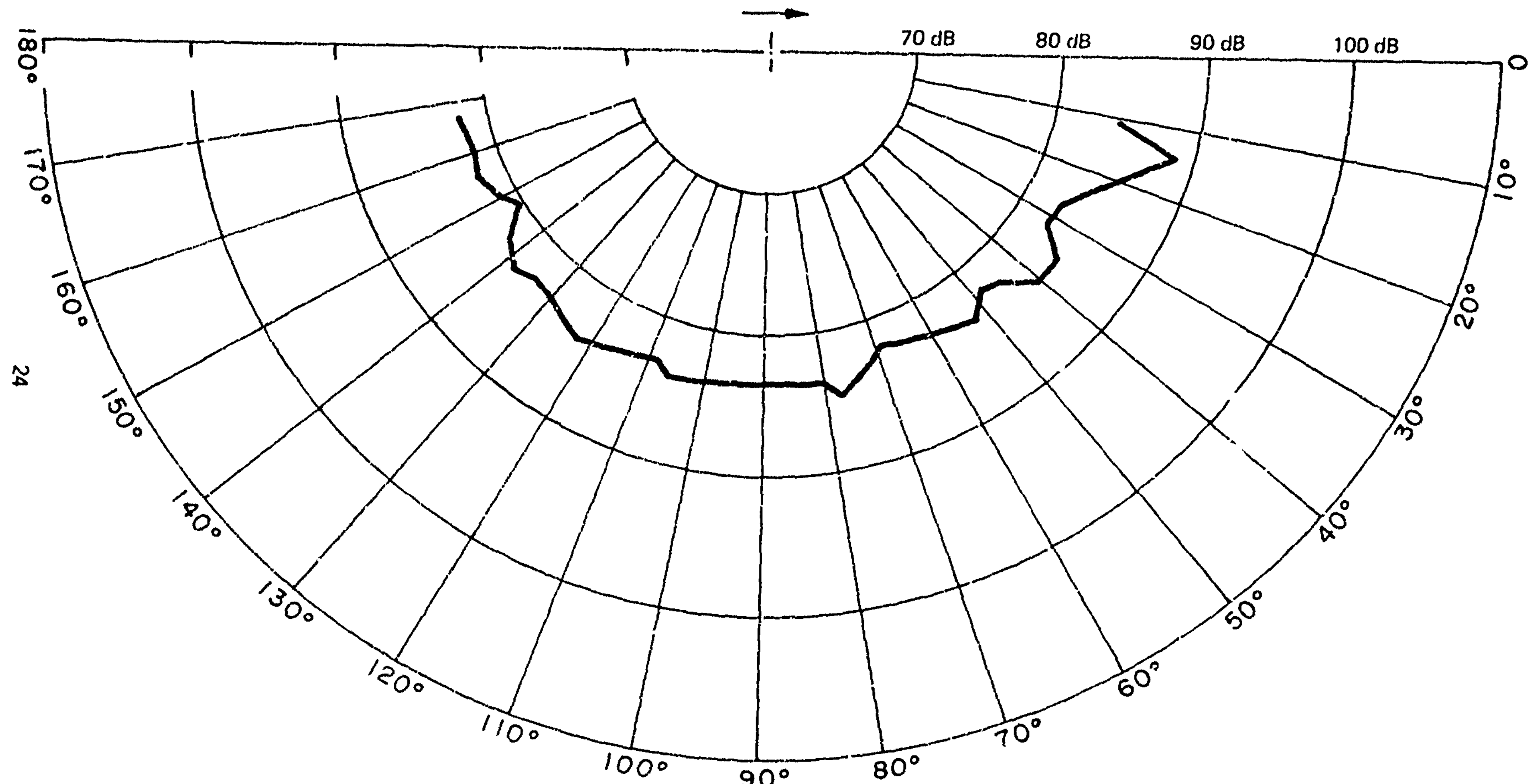

Fig. 11. Sound pressure level in the 1000Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

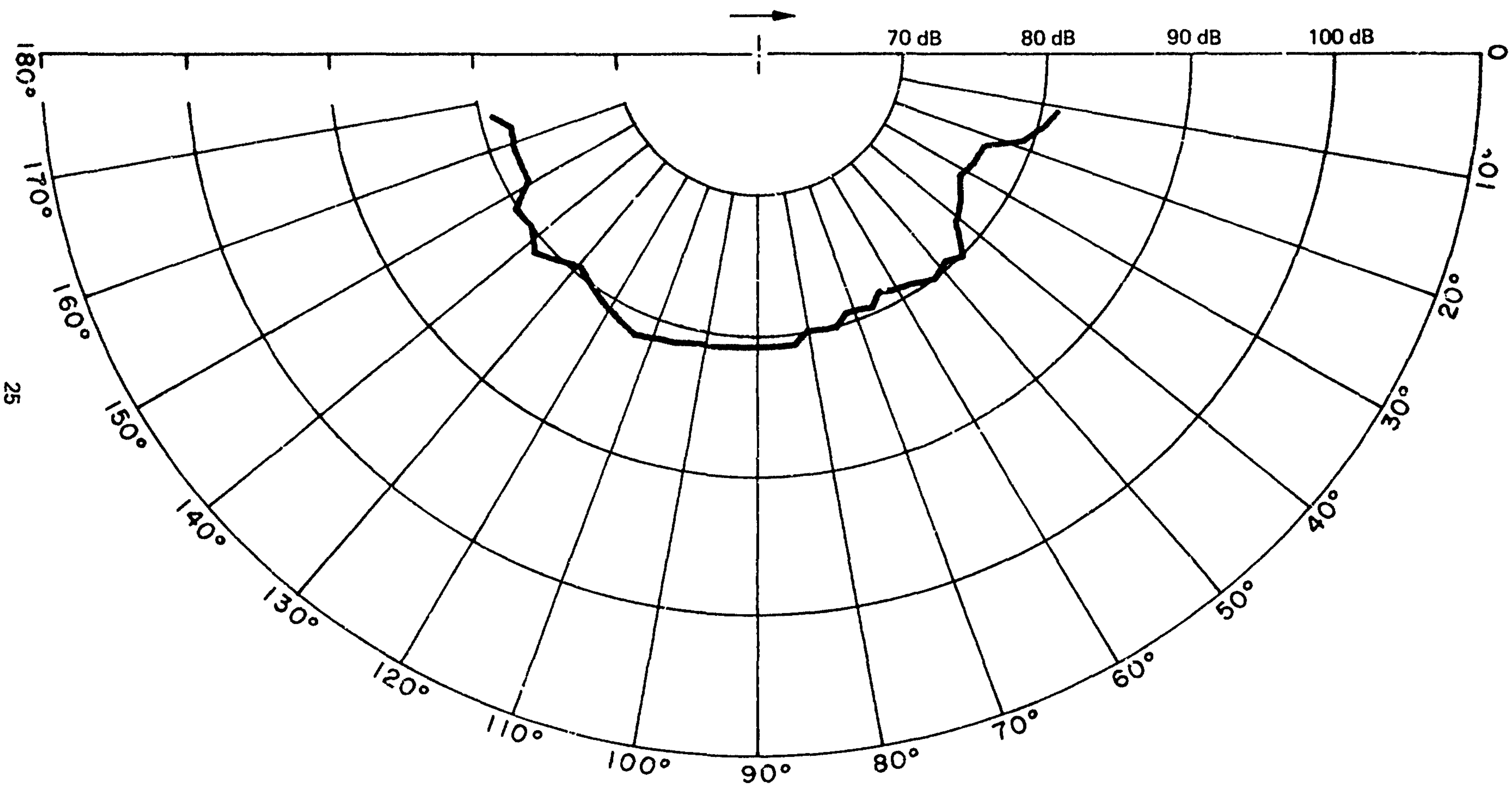

Fig. 12. Sound pressure level in the 2000 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

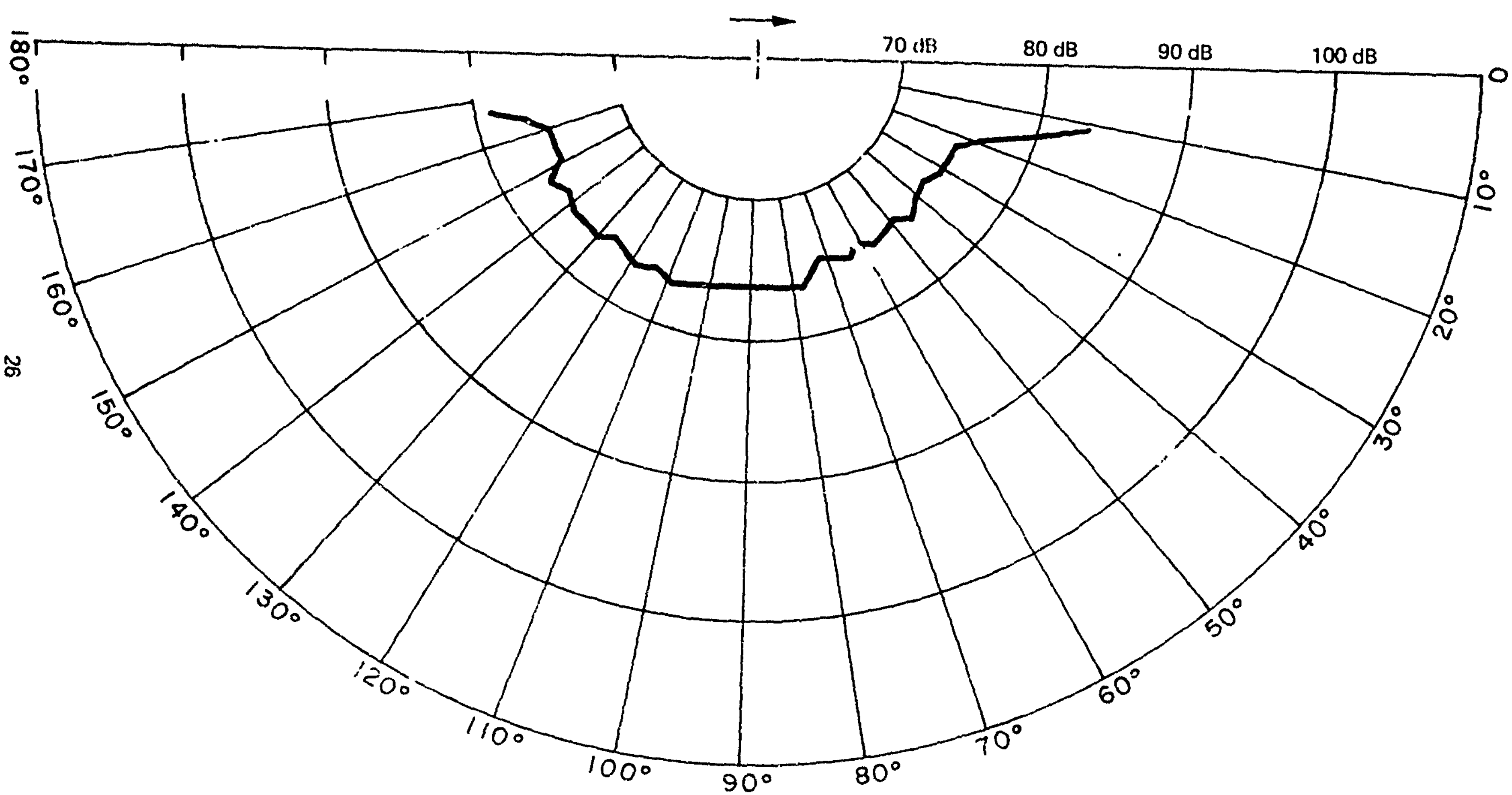

Fig. 13. Sound pressure level in the 4000 Hz octave band at 200 feet from a moving helicopter—Flight No. 1.

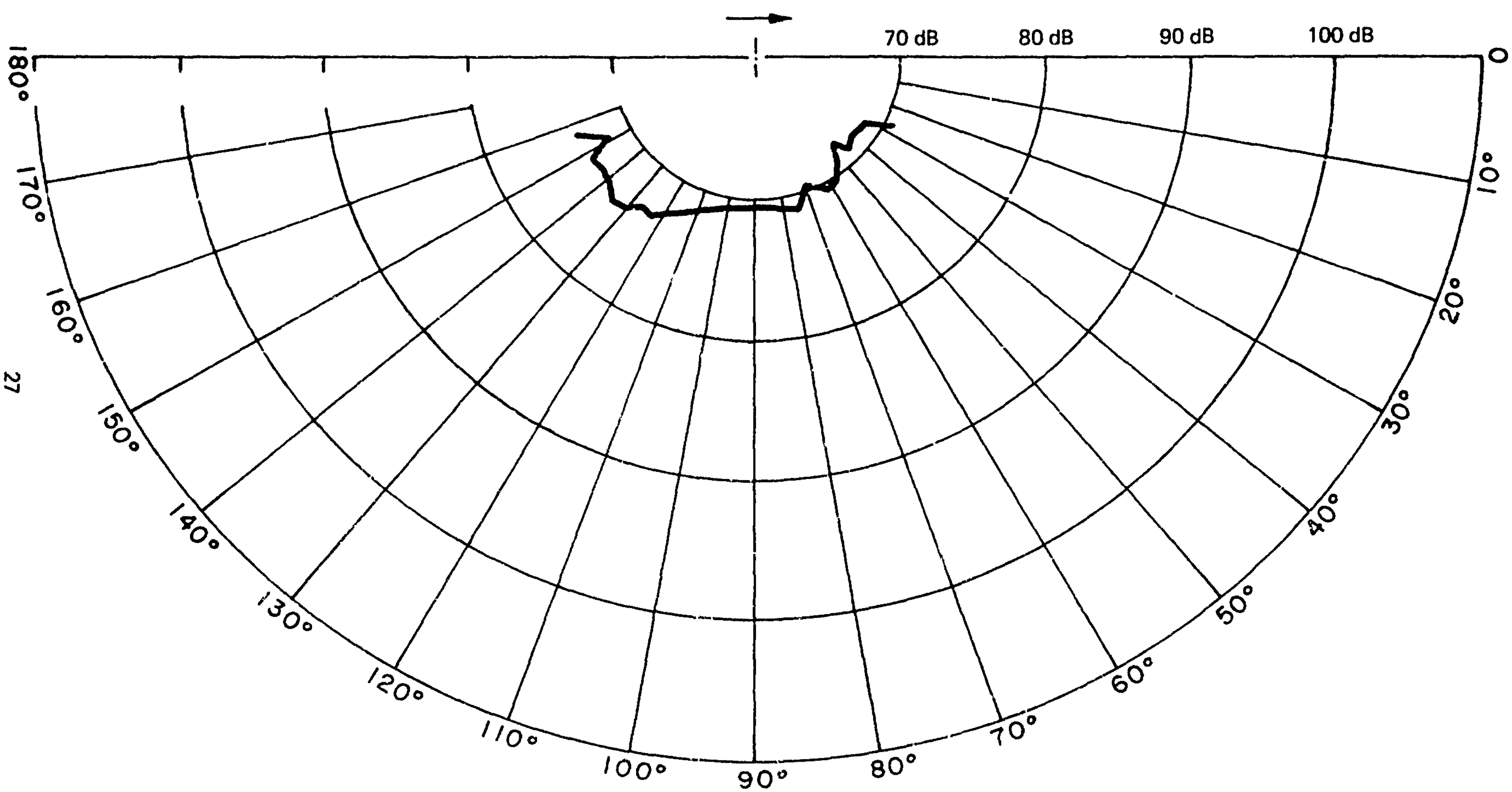

Fig. 14. Sound pressure level in the 8000 Hz octave band at 200 feet from a moving helicopter-Flight No. 1.

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APPENDIX A

SKYSCREEN SYSTEM

The skyscreen system shown in Figure 1A is used principally for measuring the velocity of projectiles in flight. This is done by a combination of optical and electronic devices. The optical portion consists of lenses and various apertures used to form a fanshaped field of view as shown in Figure 2A. The ambient light is focused on a photo cell through which an electrical current flows in proportion to the amount of incident light. The electronic circuitry is such that slow changes in light level have no effect on the output of the system. However, if a moving object enters the field of view and blocks more than approximately three percent of the sensitized area the system produces a single sharp electrical output pulse. The final portion of the skyscreen system is an electronic counter used to measure the time between two pulses. The skyscreen is mounted on a tripod which has leveling indicators as well as mechanisms for accurately aligning the lens system in azimuth and elevation.

If we now set two skyscreens a known distance apart, we can determine the velocity of an object which intercepts the field of view of each skyscreen by measuring the time it takes the object to traverse the distance.

The test set-up used during the flyover measurements is shown in Figure 3A. Switches were provided to interchange start and stop pulses so that runs could be made in either direction. The height of the aircraft was measured by using skyscreens tilted off the vertical such that their sensitive areas intersected at the nominal height chosen for each flight. For a run from left to right SS1 starts two counters while SS2 stops one counter and SS3 stops the other (Fig. 4A). The time intervals indicated by each counter will depend on whether the aircraft is at, above or below the correct altitude. If the aircraft is at the correct altitude, it will intersect the fields of SS2 and SS3 at the same instant and the two counters will show the same elapsed time. If the aircraft is high, it will intersect SS3 before SS2 and time interval 1-3 will be shorter than time 1-2. The reverse will be true if the aircraft is low.

Referring to Figure 4A, assume an aircraft with velocity V is following the path shown:

Velocity V is measured using SS1 and SS4 which are a known distance apart. Angle α is known since it is set to produce an intersection at the desired height, H_N. Angle β is known by similarity to α.

$D_1 = V(t_{1-2})$ where t_{1-2} is time interval 1–2

$D_2 = V(t_{1-3})$ where t_{1-3} is time interval 1–3

$D_3 = D_2 - D_1 = V(t_{1-3} - t_{1-2}) = V(\Delta t)$

$$\tan \beta = \frac{M}{\frac{D_3}{2}} = \frac{M}{\frac{V(\Delta t)}{2}}$$

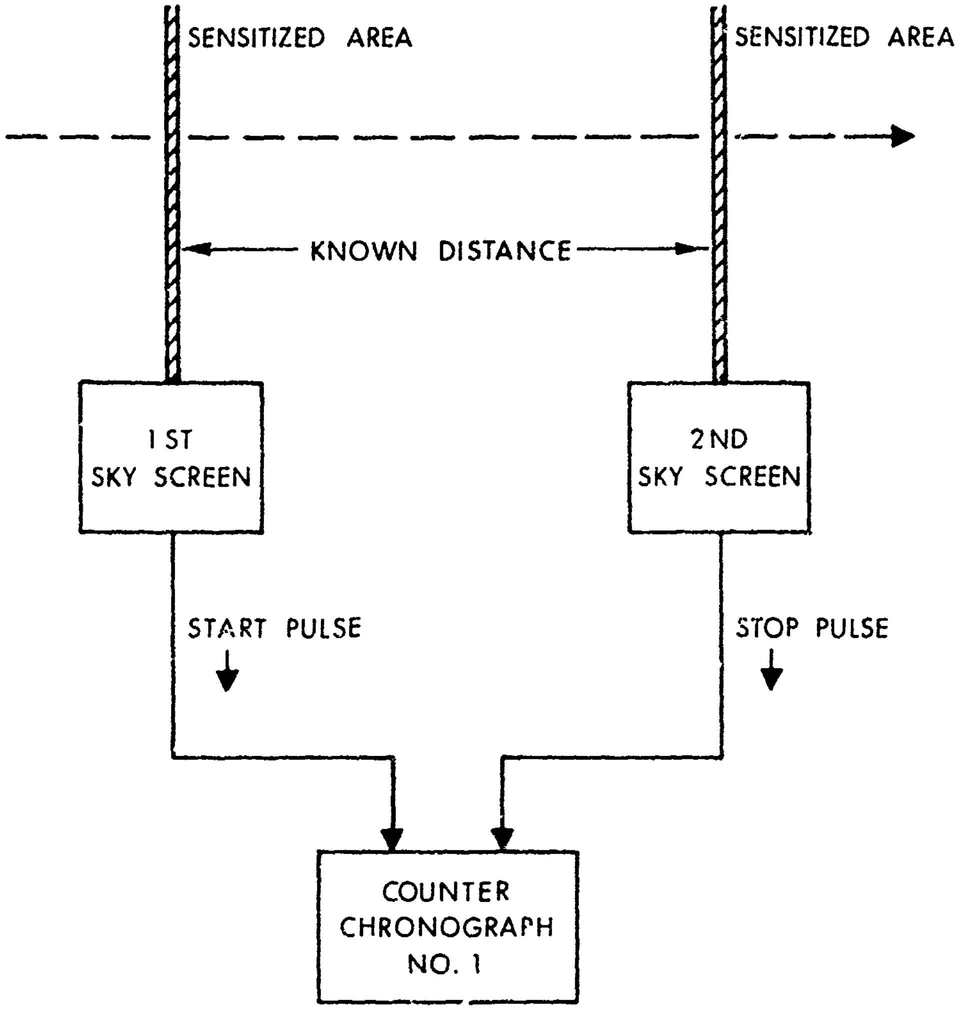

Fig. 1A. Sky-screen system.

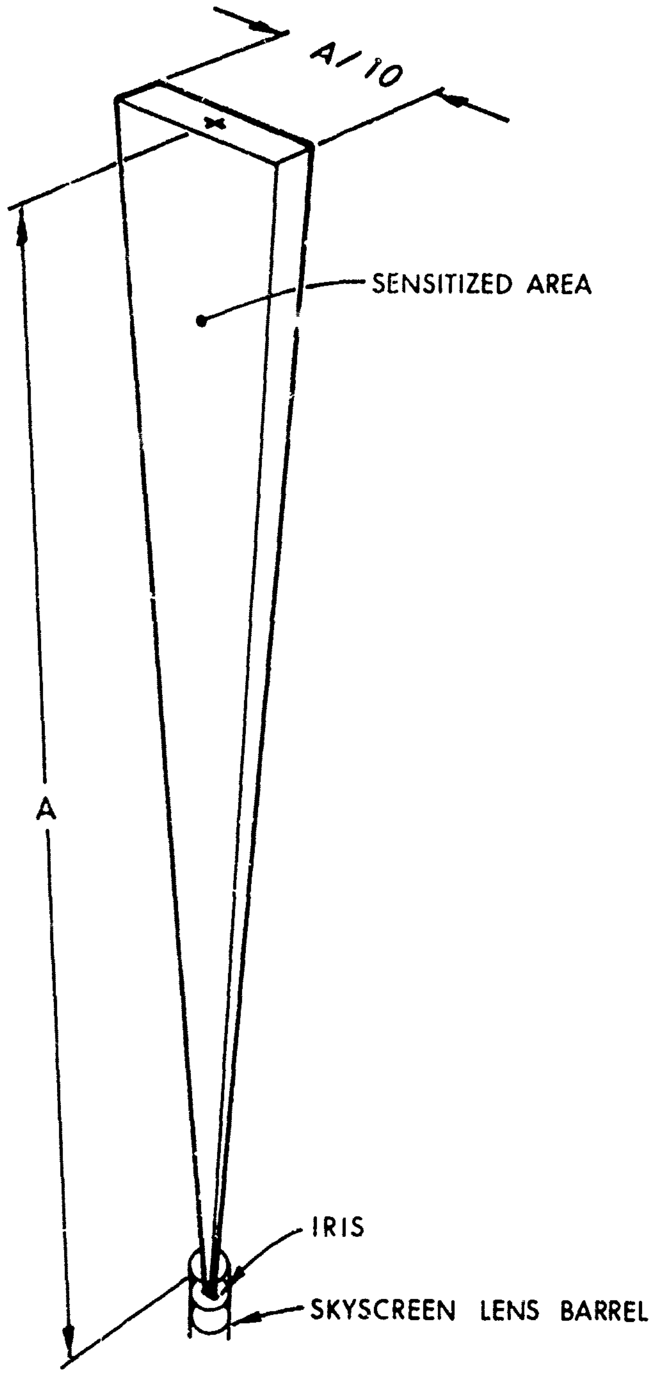

Fig. 2A. Diagram of the sensitized area of a sky screen.

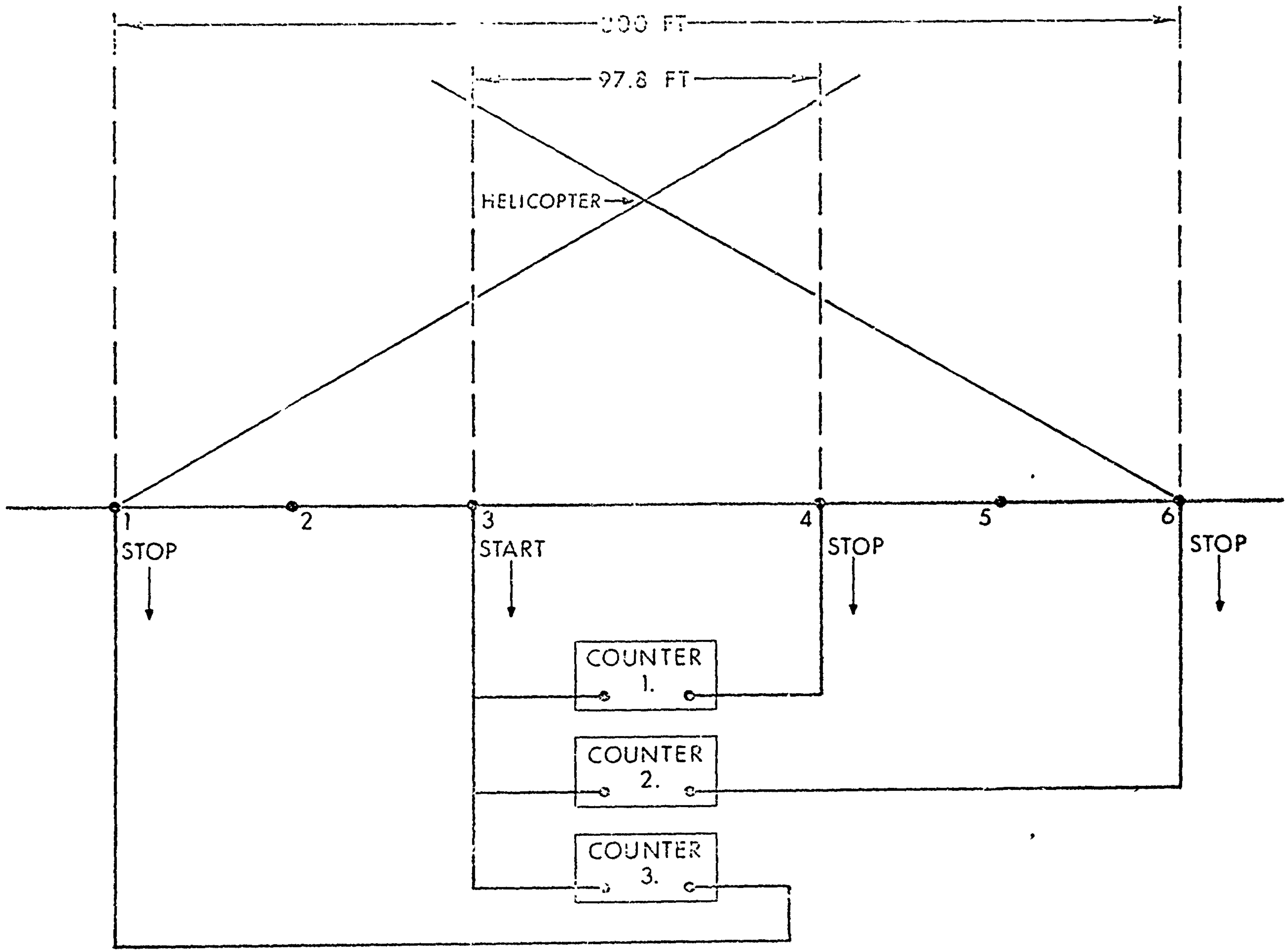

Fig. 3A. Schematic of sky-screen system.

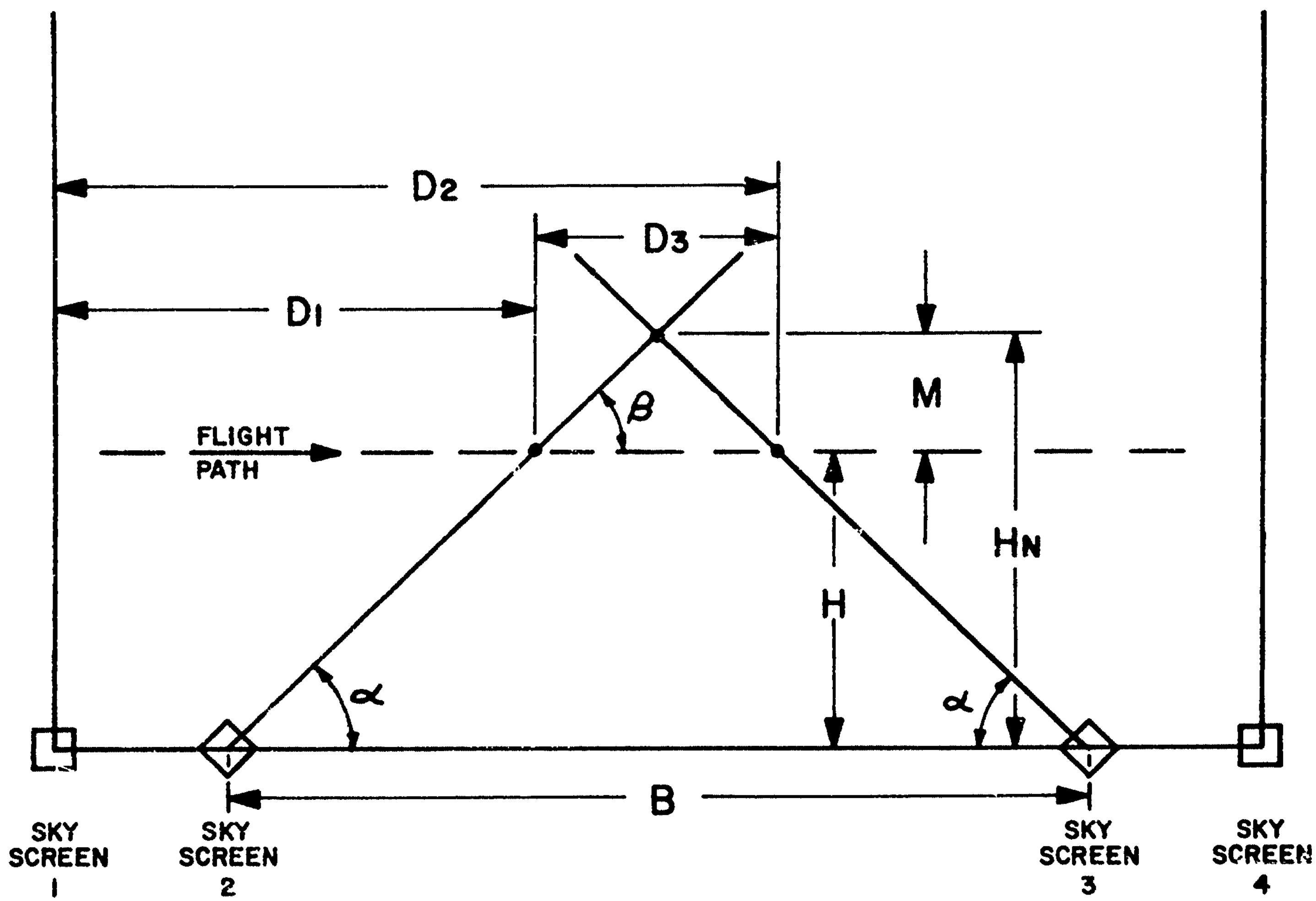

Fig. 4A. Measuring the height of an aircraft by using sky screens.

But $\tan \beta = \tan \alpha = H_N / {B/2}$

so $$M = \frac{H_N \; V(\Delta t)}{B}$$

or $$H = H_N - M$$

If the aircraft is above H_N, M will have a negative sign and will be added to H_N to give the actual height.

During the flyovers, the measuring microphone was set up within a few feet of one vertically oriented skyscreen. The pulse from this skyscreen was used to put a marker on the tape recordings to indicate the instant that the aircraft was overhead.

APPENDIX B

CALCULATIONS AND COMPUTER PROGRAM

This appendix describes the calculations and the computer program used to determine the "visual" and "sound" location of a helicopter flying a flight path directly over a microphone being used to sense the noise produced by the helicopter. Referring to Figure 1B the microphone is located at M, and the helicopter flying in the direction indicated, at speed V and height H, is located at L. Since the speed of sound is finite, the sound being received at M when the helicopter is at L was actually emitted when the helicopter was located at point L'. For any given distance, D, from the microphone:

$$S = \sqrt{D^2 + H^2}$$

$$\emptyset = \tan^{-1} \frac{H}{D}$$

$$\alpha = 180^{\circ} - \emptyset$$

By the law of cosines:

$$(S')^2 = S^2 + R^2 - 2SR \cos \alpha \quad (1)$$

Since the distance R is equal to the speed of the aircraft times the time it takes sound to travel from L' to M

$$R = V \times t$$

But time t is also equal to distance S' divided by the speed of sound C:

$$t = S/C$$

C is calculated from:

$$C = 49.03 \sqrt{T + 459.7}$$

T = temperature, degrees Fahrenheit

$$R = V \times \frac{S'}{C}$$

Substituting in (1):

$$(S')^2 = S^2 + \left(\frac{VS'}{C}\right)^2 - \frac{2SVS'}{C} \cos \alpha$$

Collecting terms:

$$(S')^2 \left(1 - \left(\frac{V}{C}\right)^2\right) + S' \left(2S \frac{V}{C} \cos \alpha\right) - S^2 = 0$$

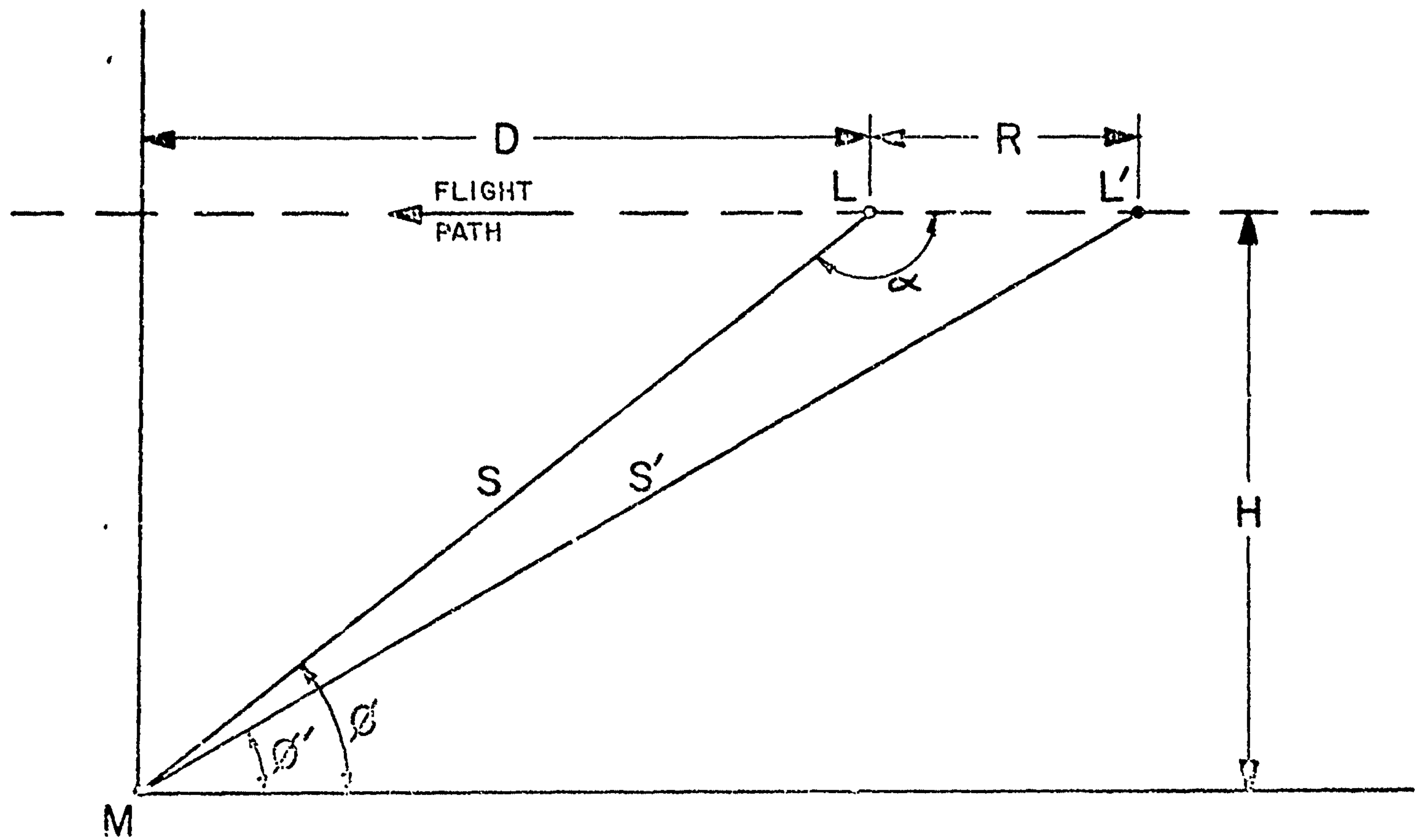

Fig. 1B Determination of actual and sound location of a helicopter in flight.

Solving for S′ :

$$S' = \frac{-(2S\frac{V}{C}\cos\alpha) \pm \sqrt{(2S\frac{V}{C}\cos\alpha)^2 - 4(1-(\frac{V}{C})^2)(-S^2)}}{2(1-(\frac{V}{C})^2)}$$

Then $\emptyset' = \arc\sin\frac{H}{S'}$

The program uses the preceding relationships along with data furnished by the operator to calculate a series of polar coordinates defining flight paths of the helicopter. In running the program the operator inputs:

(1) aircraft speed, feet per second

(2) aircraft height over microphone, feet

(3) air ambient temperature, degrees Fahrenheit

(4) ground distance to the desired starting point, feet

Input (4) was determined by examining the SPL versus time records for each flight. Since the instant that the aircraft was overhead was clearly marked on the records, we could easily determine the time in seconds to the beginning of the record. Knowing the speed, (V), of the aircraft and the time, (t), to the beginning of the record we can calculate the ground distance, (D), of the aircraft from the microphone at the beginning of the record from:

$$D_{MAX} = Vt$$

Most of our flights had a t of 60 seconds giving maximum ground distances of 6000 to 8000 feet depending on speed.

Referring to the flow chart in Figure 2B we can see that the first data points are output assuming a time t equal to zero. Time t is then advanced by a set amount and a new D is calculated which is equal to

$$D = D_{MAX} - Vt$$

where t is the time elapsed since the beginning of the record. Using the new D value a set of corresponding slant ranges and angles are calculated. The program then tests for the difference between the new angle and the last angle output. If the difference is less than three degess, time is again advanced and a new angle calculated and tested. This is done repeatedly until the difference lies in the range of three - five degrees at which time the new angle is output. We settled on this method of generating data points since the angle from an observer to a helicopter changes slowly when the helicopter is some distance away. The angle rate of change increases rapidly until it changes at a maximum rate when directly overhead, and then, once again changes at a slower and slower rate. If we had chosen to plot points at equal time intervals we would have

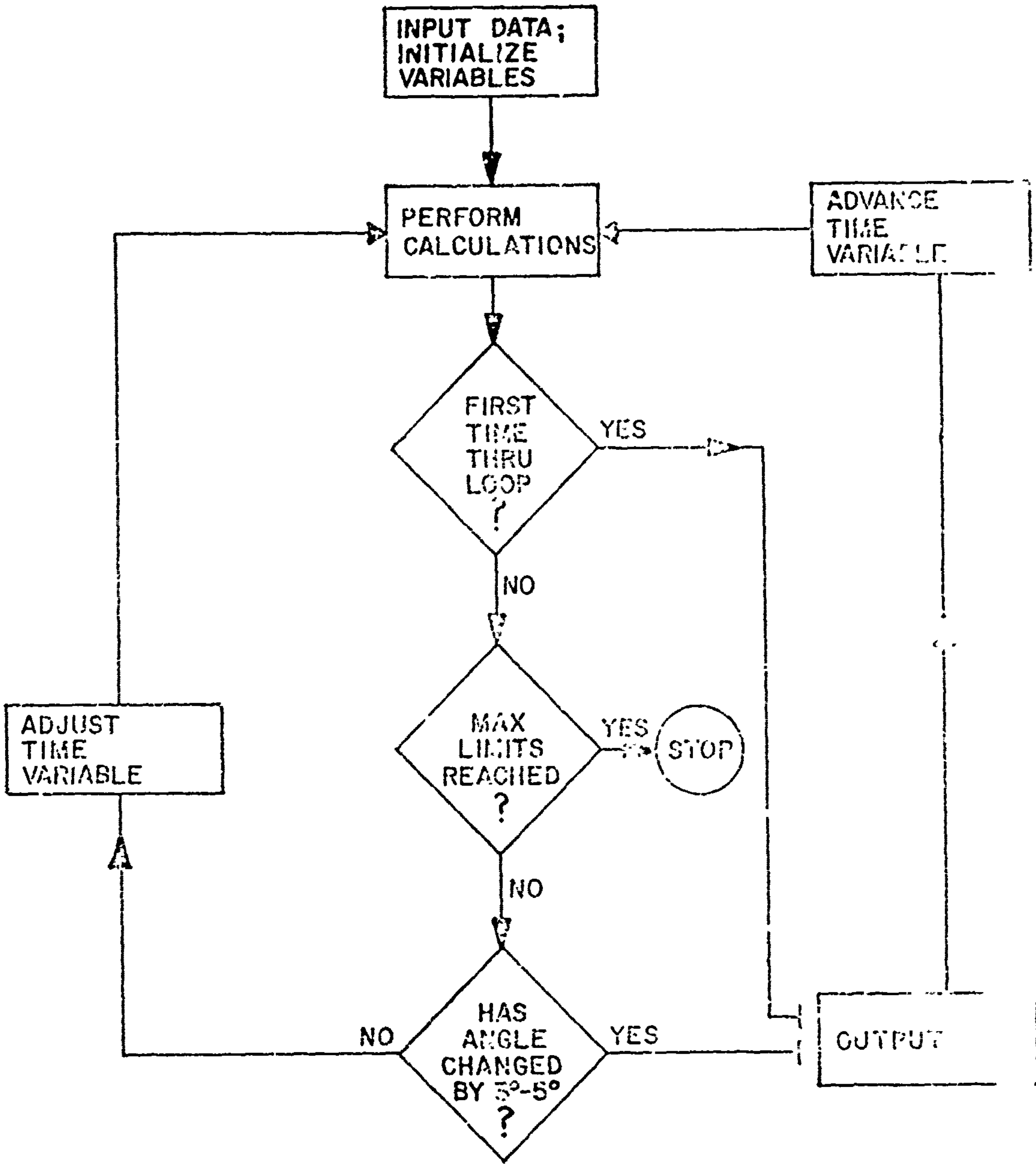

Fig. 2B. Flow chart of computer program used to calculate helicopter location.

been faced with the problem of too many points when the angle changes slowly and not enough points when the angle changes rapidly. By choosing to use equal angle intervals, time is allowed to change by a variable amount necessary to generate the chosen intervals. Consideration of the acoustic data read-out problems lead us to set 0.1 second as the minimum interval acceptable, but this posed no special problem since at our nominal values of 300 feet height and 135 feet per second speed the maximum rate of change of angle is $2.6^{o}/0.1$ second. To account for flight conditions that differed from nominal, the program was written so that it would output a data point and not "hang-up" if the minimum time change of 0.1 second produced an angle change not in the range of three to five degrees. For example, in some cases a time change of 0.1 second produced an angle change of about 2.9^{o} while a time change of 0.2 second changes the angle by 5.8^{o}. Since neither angle value is in the acceptable range, and unless this possibility is taken into account in the program, the machine will continue to oscillate between the two values and never output a value. The program was so written that if this problem occurred, the angle change associated with a minimum time change of 0.1 second would be output regardless if it met the criteria of falling in the range of three to five degrees. The program will also stop if the value of the angle exceeds 176^{o} or if the total time exceeds 180 seconds.

The complete program as written to run on the GSA RAMUS system is shown in Figure 3B.

```
C   THIS PROGRAM CALCULATES VARIOUS PARAMETERS USED IN DETERMINING
C   THE SOUND FIELD AROUND A HELICOPTER IN FLIGHT.
C
C   CALCULATIONS INCLUDE THE ANGLE ABOVE THE HORIZONTAL AND THE
C   SLANT RANGE, AT VARIOUS TIMES T,AS A HELICOPTER IN FLIGHT
C   STARTING AT ANY DESIRED GROUND RANGE,FLIES TOWARD AND DIRECTLY
C   OVER AN OBSERVER. SINCE THE SPEED OF SOUND IS FINITE, THE
C   NOISE THAT THE OBSERVER HEARS AT ANY TIME ,"T",WAS EMITTED
C   WHEN THE HELICOPTER WAS IN A LOCATION DIFFERENT FROM ITS
C   VISUAL LOCATION. THEREFORE THE PROGRAM ALSO CALCULATES
C   ANGLE AND SLANT RANGE TO EACH SOUND SOURCE LOCATION
C   CORRESPONDING TO THE ANGLE AND RANGE OF THE VISUAL LOCATION.
C
C    ASSUMPTIONS:
C                  HELICOPTER SPEED, ALTITUDE, AND HEADING ARE
C                  HELD CONSTANT.
C                  THE FLIGHT PATH PASSES DIRECTLY OVER THE OBSERVER.
C   INPUT DATA NEEDED:
C                  AIRCRAFT GROUND SPEED, IN FEET PER SECOND
C                  MAXIMUM DESIRED GROUND RANGE,IN FEET
C                  AIRCRAFT HEIGHT ABOVE OBSERVER,IN FEET
C                  AMBIENT AIR TEMPERATURE, IN DEGREES FAHRENHEIT
C
C   PROGRAM CALCULATIONS:
C                  THE PROGRAM FIRST CALCULATES THE SPEED OF SOUND
C   FOR THE GIVEN AMBIENT TEMPERATURE. THEN,AT TIME=ZERO,THE SLANT
C   RANGE AND ANGLE TO THE VISUAL LOCATION ARE CALCULATED USING THE
C   HEIGHT AND MAXIMUM GROUND RANGE. THE SLANT RANGE AND ANGLE TO
C   THE CORRESPONDING SOUND LOCATION ARE CALCULATED USING THE SPEED
C   OF SOUND AND THE VISUAL LOCATION PARAMETERS. TIME IS THEN ADVANCED
C   BY A GIVEN AMOUNT AND A NEW GROUND RANGE IS CALCULATED BY
C   REDUCING THE MAXIMUM GROUND RANGE BY AN AMOUNT EQUAL TO THE
C   DISTANCE FLOWN IN THE TIME ELAPSED FROM TIME ZERO.USING THE NEW
C   RANGE A NEW SET OF ANGLES AND SLANT RANGES ARE CALCULATED.
C   THE NEW ANGLE TO THE SOUND SOURCE IS EXAMINED TO SEE IF IT DIFFERS
C   FROM THE PREVIOUS VALUE BY FROM THREE TO FIVE DEGREES.
C   IF THE DIFFERENCE FALLS IN THE RANGE OF THREE TO FIVE DEGREES
C   THE NEW PARAMETERS ARE OUTPUT. IF THE DIFFERENCE IS LESS THAN
C   THREE DEGREES, TIME IS ADVANCED AND A NEW ANGLE IS CALCULATED.
C   MINIMUM TIME ADVANCE BETWEEN OUTPUT POINTS IS 0.1 SECONDS
C   EVEN IF THIS ADVANCE PRODUCES AN ANGLE CHANGE GREATER THAN
C   FIVE DEGREES OR LESS THAN THREE DEGREES.
C
C   SYMBOL TABLE:
C                    T=TIME,SECONDS
C                    N=ARBITRARY INTEGER
C                    PI=CONSTANT=3.14159
C                    CSND= SPEED OF SOUND IN AIR,FEET PER SECOND
C                    PHIDEL=STORAGE LOCATION FOR LAST ANGLE OUTPUT
C                    TEMP=AMBIENT AIR TEMPERATURE,DEGREES FAHRENHEIT
```

Fig. 3B. FORTRAN program used to calculate helicopter location.

```
C                   VEL=AIRCRAFT GROUND SPEED, FEET PER SECOND
C                   ALT=AIRCRAFT HEIGHT ABOVE OBSERVER,FEET
C                   DVTZRO=MAX GROUND DISTANCE TO AIRCRAFT,FEET
C                   DV=GROUND DISTANCE TO VISUAL POSITION AT TIME,T:FEET
C                   SV=SLANT RANGE TO VISUAL POSITION AT TIME,T:FEET
C                   PHV=ANGLE ABOVE HORIZONTAL TO VISUAL LOCATION,RADIANS
C                   DA=GROUND DISTANCE TO SOUND LOCATION AT TIME,T:FEET
C                   SA=SLANT RANGE TO SOUND LOCATION AT TIME,T:FEET
C                   PHA=ANGLE ABOVE HORIZONTAL TO SOUND LOCATION,RADIANS
C                   DD=DIFFERNCE BETWEEN DA AND DV
C                   PHVDEG AND PHADEG ARE THE DEGREE EQIVALENTS OF
C                   PHV AND PHA
C
C
C     THE FOLLOWING IS A LIST OF FORMATS USED
C
 1    FORMAT(F6.1,2(2X,F6.1,2X,F8.1))
 2    FORMAT(21HAIRCRAFT SPEED......=,F8.1,13H FEET PER SEC)
 3    FORMAT(21HGROUND DIST AT TZERO=,F8.1,5H FEET)
 4    FORMAT(21HHEIGHT OF AIRCRAFT..=,F8.1,5H FEET)
 5    FORMAT(21HAMBIENT AIR TEMP....=,F8.1,10H DEGREES F)
C
C     SET INITIAL VALUES
C
      T=0.
      N=0
      PHDEL=0.
      PI=3.14159
C
C     INPUT DATA
C
      PRINT,"WHAT IS AIRCRAFT SPEED, IN FEET PER SECOND?"
      INPUT,VEL
      PRINT,"WHAT IS MAXIMUM GROUND DISTANCE TO AIRCRAFT,IN FEET?"
      INPUT,DVTZRO
      PRINT,"WHAT IS HEIGHT OF AIRCRAFT ABOVE OBSERVER,IN FEET?"
      INPUT,ALT
      PRINT,"WHAT IS AMBIENT AIR TEMPERATURE,IN DEGREES F?"
      INPUT,TEMP
C
C     PRINT HEADINGS FOR OUTPUT TABLE.(A "↑" INDICATES A LINE FEED)
C
      PRINT,↑2,↑2," TIME     PHV       SV      PHA       SA"
      PRINT,"  SEC      DEG      FEET     DEG      FEET",↑
C
C     CALCULATE THE SPEED OF SOUND
C
      CSND=49.03*SQRT(TEMP+459.7)
C
C     CALCULATE DV,SV,PHV,ALPH,DA,SA,PHA,DD
```

```
C
   10 DV=DVTZRO-VEL*T
      SV=SQRT(DV**2+ALT**2)
      PHV=ATAN(ABS(ALT/DV))
C     ALPH=PHV UNLESS DV IS GREATER THAN ZERO
C
      ALPH=PHV
      IF(DV.GT.Ø.Ø)ALPH=PI-PHV
C
C     CALCULATE COEFFICIENTS FOR QUADRATIC
C
      A=1.-(VEL/CSND)**2
      B=2.*SV*(VEL/CSND)*COS(ALPH)
      C=-SV**2
C
C     CHECK FOR REAL ROOTS:IF NOT GOTO ERROR MESSAGE
C
      IF(B**2-4.*A*C.LT.Ø.Ø)GOTO 33
C
C     SOLVE FOR SA USING POSITIVE ROOT ONLY
C
      SA=(-B+SQRT(B**2-4.*A*C))/(2.*A)
      DD=SA*VEL/CSND
      DA=SQRT(SA**2-ALT**2)
      PHA=ATAN(ABS(ALT/DA))
C
C     ADJUST PHV AND PHA TO PROPER QUADRANT
C
      IF(DV+DD.LE.Ø.Ø)PHA=PI-PHA
      IF(DV.LE.Ø.Ø)PHV=PI-PHV
C
C     IF T IS LESS THAN Ø.1,THIS IS FIRST TIME THROUGH;GOTO OUTPUT.
C
      IF(T.LT.Ø.1)GOTO 24
C
C     AFTER THE INITIAL CALCULATIONS(WITH T=Ø), THE FOLLOWING SECTION
C     CHECKS THAT THE CHANGE IN PHA AS TIME IS INCREASED FALLS IN THE
C     RANGE OF THREE TO FIVE DEGREES OR TIME IS INCREASED BY A MINIMUM
C     OF Ø.1 SEC REGARDLESS OF THE RESULTING CHANGE IN PHA.
C
      IF(PHA-PHDEL.GT.3.*PI/18Ø.) GOTO 6
      IF(N.GT.4) GOTO 24
      GOTO 35
    6 IF(PHA-PHDEL.LT.5.*PI/18Ø.) GOTO 24
      N=N+1
      IF(N.EQ.5) GOTO 23
      T=T-Ø.1
      GOTO 1Ø
C
C      THE FOLLOWING IS THE OUTPUT SECTION
```

```
C
   20 PHDEL=PHA
      N=0
C     CONVERT PHA AND PHV TO DEGREES
      PHADEG=PHA*180./PI
      PHVDEG=PHV*180./PI
C
C     OUTPUT CALCULATED VALUES
C
      PRINT1,T,PHVDEG,SV,PHADEG,SA
C
C     CHECK IF MAX VALUES FOR T OR PHA HAVE BEEN EXCEEDED
C
   30 IF(T.GT.180..OR.PHADEG.GT.170.) GOTO 25
C
C     IF MAX VALUES NOT EXCEEDED, INCREASE TI    AND HAVE NEW VALUES CALC  .
C
      T=T+0.5
      GOTO 10
C     THE FOLLOWING SECTION OUTPUTS THE DATA USED IN THE CALCULATIONS
C
   25 PRINT,12,"DATA USED",↑
      PRINT2,VEL
      PRINT3,DVTZRO
      PRINT4,ALT
      PRINT5,TEMP
      PRINT,↑,"                              END OF FLIGHT"
      STOP
C
C     ERROR MESSAGE
C
   30 PRINT,"ERROR IN DATA:CALCULATIONS INDICATE IMAGINARY ROOTS FOR  N.
      GOTO 25
      STOP
      END
```

APPENDIX C

MEASURED SOUND PRESSURE LEVELS AND CORRESPONDING HELICOPTER LOCATION DATA FOR FLIGHTS 1 THROUGH 7

TABLE 1C

Measured Sound Pressure Levels and Corresponding Helicopter Location Data for Flight No. 1

[illegible] #	[illegible]	[illegible] ANGLE, DEGREES	[illegible] RANGE, FEET	[illegible] LOCATION ANGLE, DEGREES	[illegible] RANGE, FEET	DECIBEL [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			-		-	-	-
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61	-	-	-
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
4	[illegible]	[illegible]	1181.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52	-
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57	-
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	57
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	320.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	63
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	75.6	[illegible]	[illegible]	258.2	82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	59.6	[illegible]	246.4	[illegible]	[illegible]	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	244.2	[illegible]	250.2	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	84.1	[illegible]	77.6	[illegible]	81	[illegible]	[illegible]	[illegible]	[illegible]	78	73	63
23	[illegible]	87.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83	78	74	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	107.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	255.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	66	[illegible]
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	[illegible]	-
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51	-
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	-	-
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-

TABLE 2C

Measured Sound Pressure Levels and Corresponding
Helicopter Location Data for Flight No. 2

DATA POINT N	TIME FROM START, SEC	VISUAL LOCATION ANGLE, DEGREES	VISUAL SLANT RANGE, FEET	SOUND LOCATION ANGLE, DEGREES	SOUND SLANT RANGE, FEET	MEASURED OCTAVE BAND SOUND PRESSURE LEVELS, DB — OCTAVE BAND CENTER FREQUENCIES, HZ 63	125	250	500	1K	2K	4K	8K
1	0.0	2.9	5446.3	[illegible]	5993.1	77	75	67	60	50	-	-	-
2	30.0	6.3	2487.3	5.7	2735.9	89	90	82	68	59	50	-	-
3	39.0	9.7	1605.5	[illegible]	1764.5	92	92	75	70	65	50	-	-
4	43.5	13.4	1159.2	12.2	1283.6	94	93	83	72	66	52	-	-
5	46.0	16.9	930.5	15.9	1020.0	95	94	84	79	72	56	51	-
6	48.0	21.4	742.5	19.5	813.1	96	94	82	82	71	61	54	-
7	49.5	26.5	607.0	24.2	662.5	97	93	83	85	73	63	57	-
8	50.5	31.4	521.2	28.6	566.0	97	92	85	87	74	65	59	-
9	51.3	36.5	455.5	33.6	492.3	97	90	88	86	75	65	60	-
10	51.8	40.6	416.8	37.2	448.2	96	86	88	85	77	68	62	54
11	52.3	45.4	380.6	41.7	407.6	94	84	88	86	78	69	64	55
12	52.7	50.6	354.6	46.0	377.6	94	83	87	88	73	70	65	56
13	53.1	55.2	324.9	51.0	349.1	92	84	88	89	78	71	66	58
14	53.4	59.7	314.0	55.2	330.2	91	85	88	88	79	72	67	59
15	53.7	64.6	300.1	59.1	317.5	87	86	[illegible]	86	78	73	68	61
16	53.9	68.1	292.2	63.3	303.6	87	88	[illegible]	86	77	74	69	62
17	54.1	71.8	285.4	66.9	294.3	87	90	90	86	78	75	70	63
18	54.3	75.7	279.4	70.6	287.5	85	91	90	86	78	75	71	64
19	54.5	79.7	275.7	74.5	281.4	82	92	90	86	78	76	71	65
20	54.7	83.8	273.0	78.5	276.7	81	[illegible]	90	86	79	76	72	65
21	54.9	87.9	271.4	82.7	273.4	81	92	90	84	80	76	72	66
22	55.1	92.1	271.8	86.9	271.6	81	92	89	83	80	77	72	67
23	55.3	96.2	272.8	91.6	271.2	82	92	89	83	82	76	73	67
24	55.5	100.3	275.2	95.2	272.7	80	91	89	84	83	78	73	67
25	55.7	104.3	279.9	99.2	274.8	80	91	88	84	82	78	73	67
26	55.9	108.2	285.4	103.2	278.6	79	87	88	84	80	77	73	67
27	56.1	111.9	292.2	107.0	283.6	79	87	87	85	80	77	73	67
28	56.3	115.4	300.1	110.6	289.0	79	87	87	86	80	77	73	67
29	56.5	118.7	309.1	114.1	297.1	78	88	86	86	81	77	73	67
30	56.8	123.3	324.6	118.9	309.3	78	88	85	84	81	77	73	67
31	57.1	127.6	341.6	123.3	324.4	77	86	82	83	80	77	72	66
32	57.4	131.7	360.4	127.3	340.7	73	86	79	83	80	76	71	65
33	57.7	135.6	387.6	131.4	364.6	74	84	79	81	79	75	70	64
34	58.3	140.7	424.3	136.9	397.1	75	83	80	79	76	73	68	61
35	58.8	144.2	463.5	141.1	432.1	79	82	81	77	74	72	66	59
36	59.3	147.5	508.4	144.7	468.8	78	80	82	77	73	70	64	57
37	59.8	150.1	546.7	147.2	507.1	79	78	82	77	72	70	63	55
38	60.8	154.7	634.5	152.5	586.5	76	74	80	73	70	65	59	53
39	61.8	158.0	725.1	156.1	668.9	77	73	76	70	68	64	56	-
40	63.3	161.7	864.5	160.1	795.8	81	72	77	70	65	60	53	-
41	65.3	165.1	1154.2	163.7	1065.1	79	71	68	68	62	58	-	-
42	67.8	167.9	1594.6	166.5	1187.7	74	71	64	66	60	54	-	-
43	71.8	170.7	1603.5	169.4	1544.6	73	68	60	65	54	50	-	-
44	79.3	173.6	2418.5	172.4	2217.6	-	65		-	50	-	-	-
45	97.5	176.7	4341.6	175.1	3883.	-	60	-	-	-	-	-	-

TABLE 3C

Measured Sound Pressure Levels and Corresponding Helicopter Location Data for Flight No. 3

[illegible]	[illegible]	[illegible] DEGREES	[illegible] FEET	[illegible] DEGREES	[illegible] FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	66
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	74	67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79	74	68
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42	41	86	[illegible]	79	74	68
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79	74	69
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	74	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	74	69
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	72	68
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	72	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	69	62
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	[illegible]	60
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75	72	66	58
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62	54
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	58	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	69	63	54	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61	51	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]		-	50	-	-

TABLE 4C

Measured Sound Pressure Levels and Corresponding Helicopter Location Data for Flight No. 4

DATA POINT N	TIME FROM START, SEC	[illegible] LOCATION ANGLE, DEGREES	[illegible] SLANT RANGE, FEET	[illegible] LOCATION ANGLE, DEGREES	[illegible] SLANT RANGE, FEET	MEASURED OCTAVE BAND SOUND PRESSURE LEVELS, DB — OCTAVE BAND CENTER FREQUENCIES, HZ: 63	125	250	500	1K	2K	4K	8K
1	0.1	2.9	[illegible]	2.1	[illegible]	[illegible]		[illegible]	-	-	-	-	-
2	35.[illegible]	5.[illegible]	[illegible]	5.2	2982.0	[illegible]	[illegible]	86	[illegible]	66	-	-	-
3	45.0	[illegible]	[illegible]	[illegible]	1890.[illegible]	92	92	85	71	64	52	-	-
4	49.5	13.3	[illegible]	12.6	1304.2	95	95	87	75	71	54	-	-
5	52.0	17.1	[illegible]	15.6	[illegible]	96	95	86	[illegible]	73	59	50	-
6	53.5	21.[illegible]	758.[illegible]	18.4	852.9	97	95	85	82	70	60	52	-
7	54.5	24.3	650.1	22.6	725.1	98	95	85	84	74	63	54	-
8	55.5	28.[illegible]	560.5	[illegible]	615.4	98	94	[illegible]	85	[illegible]	65	57	-
9	56.3	33.4	486.1	30.7	531.2	98	92	84	[illegible]	75	66	59	-
10	56.[illegible]	37.9	441.[illegible]	34.3	481.0	97	90	90	82	76	68	62	59
11	57.3	42.7	400.[illegible]	38.8	433.3	96	87	90	[illegible]	[illegible]	69	63	58
12	57.7	47.3	369.4	43.0	397.6	96	85	88	83	77	71	64	55
13	58.0	51.2	348.1	46.7	372.7	94	83	[illegible]	86	78	71	65	56
14	58.[illegible]	55.7	328.[illegible]	50.4	349.6	93	83	85	[illegible]	78	71	65	57
15	58.6	60.6	311.3	55.6	328.7	91	95	89	87	79	72	67	59
16	58.8	64.3	301.2	59.1	316.3	88	86	90	87	79	74	69	61
17	59.0	68.1	292.4	62.8	305.1	87	88	91	[illegible]	79	75	69	61
18	59.2	72.2	285.0	66.7	295.4	87	89	91	87	[illegible]	75	69	62
19	59.4	76.4	[illegible]	70.8	287.2	85	91	91	87	78	75	70	63
20	59.6	80.4	[illegible]	75.2	280.6	84	91	91	87	78	76	71	64
21	59.8	85.4	[illegible]	79.7	275.8	82	91	91	86	78	76	72	65
22	60.0	90.0	271.3	84.[illegible]	272.[illegible]	81	91	91	85	79	77	72	66
23	60.2	94.6	272.2	88.8	271.4	80	91	91	85	79	77	[illegible]	67
24	60.4	99.1	274.8	93.4	271.8	80	91	90	85	80	78	73	67
25	60.6	103.6	279.1	97.9	273.4	80	91	90	85	80	78	73	67
26	60.[illegible]	107.8	285.0	102.[illegible]	277.7	80	90	89	85	80	77	72	67
27	61.0	111.9	292.4	106.5	283.0	79	89	88	85	81	78	72	67
28	61.2	115.[illegible]	301.2	110.5	289.7	79	88	88	85	81	77	72	~~62~~ 67
29	61.4	119.4	311.[illegible]	114.[illegible]	297.7	79	88	86	85	81	77	72	~~62~~ [illegible]
30	61.6	122.7	322.[illegible]	117.[illegible]	306.[illegible]	79	87	[illegible]	84	81	77	72	~~61~~ [illegible]
31	61.8	127.6	341.[illegible]	122.8	322.[illegible]	79	86	85	84	81	77	71	~~61~~ 66
32	62.[illegible]	131.5	[illegible]	127.2	340.4	78	86	[illegible]	83	81	76	71	65
33	62.5	135.1	384.5	131.3	359.[illegible]	78	85	82	82	80	75	70	64
34	[illegible]	[illegible]	416.6	135.6	387.8	78	84	81	80	[illegible]	74	69	62
35	[illegible]	143.8	454.3	140.5	425.5	78	83	81	79	77	72	67	60
36	[illegible]	147.5	[illegible]	144.5	465.5	[illegible]	81	81	[illegible]	75	70	65	57
37	[illegible]	150.5	551.6	147.7	507.2	[illegible]	[illegible]	81	76	73	69	63	55
38	[illegible]	[illegible]	[illegible]	152.6	565.5	80	76	[illegible]	75	71	66	59	-
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	73	[illegible]	73	69	64	57	-
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	72	73	[illegible]	66	61	53	-
41	[illegible]	[illegible]	[illegible]	[illegible]	1119.5	77	72	[illegible]	71	66	60	51	-
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75	76	[illegible]	[illegible]	58	51	-	-
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	-	-

TABLE 5C

Me asured Sound Pressure Levels and Corresponding Helicopter Location Data for Flight No. 5

TABLE 6C

Measured Sound Pressure Levels and Corresponding Helicopter Location Data for Flight No. 6

DATA POINT N	TIME FROM START, SEC	[illegible] LOCATION ANGLE, DEGREES	[illegible], FEET	[illegible] LOCATION ANGLE, DEGREES	[illegible] RANGE, FEET	MEASURED OCTAVE BAND SOUND PRESSURE LEVELS, dB — OCTAVE BAND CENTER FREQUENCIES, HZ: 63	125	250	500	1K	2K	4K	8K
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-		-	-	-	-
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56	-	-
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	68	56	-	-
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	55	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84	[illegible]	[illegible]	64	55	-
[illegible]	45.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74	65	58	-
[illegible]	[illegible]	[illegible]	[illegible]	33.6	[illegible]	98	90	[illegible]	[illegible]	73	66	59	-
[illegible]	[illegible]	41.6	[illegible]	[illegible]	[illegible]	[illegible]	86	91	[illegible]	[illegible]	67	61	-
11	[illegible]	45.3	[illegible]	[illegible]	[illegible]	[illegible]	82	90	[illegible]	75	68	62	-
12	[illegible]	50.6	[illegible]	45.[illegible]	[illegible]	96	[illegible]	[illegible]	85	76	68	63	54
13	[illegible]	[illegible]	[illegible]	50.4	[illegible]	94	83	[illegible]	86	[illegible]	69	64	55
14	48.4	60.1	[illegible]	55.1	[illegible]	93	[illegible]	[illegible]	86	78	70	65	56
15	[illegible]	[illegible]	336.6	59.7	352.[illegible]	89	86	[illegible]	84	[illegible]	71	66	57
16	48.9	[illegible]	[illegible]	[illegible]	341.[illegible]	88	88	[illegible]	83	76	72	67	58
17	49.1	72.1	[illegible]	66.5	332.1	87	89	90	83	76	73	68	59
18	49.3	[illegible]	[illegible]	[illegible]	323.8	84	90	90	82	76	74	68	61
19	49.5	[illegible]	[illegible]	74.1	316.8	83	91	[illegible]	82	77	74	69	62
20	49.7	[illegible]	[illegible]	[illegible]	311.[illegible]	81	91	90	82	77	74	70	63
21	49.9	[illegible]	[illegible]	82.1	[illegible]	80	91	90	83	78	75	70	63
22	50.1	92.1	304.9	86.3	305.3	80	91	90	87	79	75	70	64
23	50.3	96.2	306.5	90.4	304.[illegible]	[illegible]	91	[illegible]	83	79	75	71	64
24	50.5	100.2	309.[illegible]	94.5	305.6	79	90	[illegible]	84	80	76	71	64
25	50.7	104.1	314.2	98.[illegible]	[illegible]	79	90	[illegible]	84	80	76	72	65
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79	[illegible]	87	84	80	77	72	65
27	51.1	111.[illegible]	[illegible]	[illegible]	[illegible]	79	[illegible]	86	85	81	77	72	65
28	51.3	115.1	[illegible]	109.8	323.[illegible]	79	88	85	85	81	77	72	65
29	51.5	[illegible]	[illegible]	113.2	331.[illegible]	[illegible]	86	84	[illegible]	[illegible]	77	72	64
[illegible]	[illegible]	[illegible]	[illegible]	119.1	[illegible]	79	85	[illegible]	84	[illegible]	76	71	64
[illegible]	52.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	75	71	63
[illegible]	52.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	81	[illegible]	74	[illegible]	62
[illegible]	[illegible]	[illegible]	[illegible]	131.1	[illegible]	78	83	80	81	[illegible]	74	69	61
34	53.2	[illegible]	[illegible]	[illegible]	[illegible]	78	83	80	78	[illegible]	73	67	60
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	[illegible]	80	[illegible]	[illegible]	71	66	58
36	[illegible]	146.5	[illegible]	[illegible]	509.[illegible]	78	80	80	75	[illegible]	70	65	56
37	[illegible]	[illegible]	[illegible]	[illegible]	551.2	[illegible]	77	81	75	[illegible]	68	62	54
38	[illegible]	[illegible]	[illegible]	151.1	[illegible]	[illegible]	[illegible]	[illegible]	75	71	65	59	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	[illegible]	[illegible]	[illegible]	62	55	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70	[illegible]	70	66	60	53	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	70	[illegible]	67	[illegible]	58	51	-
[illegible]	[illegible]	[illegible]	[illegible]	164.5	[illegible]	77	[illegible]	[illegible]	66	60	55	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	67	66	60	55	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	-	-	-

TABLE 7

Measured Sound Pressure Levels and Corresponding
Helicopter Location Data for Flight No. 7

APPENDIX D

CALCULATED SOUND PRESSURE LEVELS AT A CONSTANT DISTANCE OF 200 FEET AND CORRESPONDING ANGLES FOR FLIGHTS 1 THROUGH 7

TABLE 1D

Calculated Sound Pressure Levels at a Constant Distance of
200 Feet and Corresponding Angles for Flight No. 1

DATA POINT N	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, dB, AT 200 FEET FROM SOUND SOURCE — OCTAVE BAND CENTER FREQUENCIES, Hz: 63	125	250	500	1K	2K	4K	8K
1	[illegible]	-	-	-	-	-	-		-
2	[illegible]	-	-	-	-	-	-	-	-
3	[illegible]	-	-	-	-	-	-	-	-
4	11.4	[illegible]	116	98	96	95	91	83	-
5	[illegible]	[illegible]	105	99	99	89	81	80	-
6	[illegible]	[illegible]	110	110	[illegible]	86	79	77	-
7	[illegible]	106	99	99	93	85	77	75	-
8	[illegible]	104	[illegible]	96	93	93	77	75	71
9	[illegible]	101	[illegible]	95	93	93	77	75	69
10	[illegible]	99	94	95	95	85	77	77	69
11	[illegible]	[illegible]	91	96	95	85	78	75	69
12	[illegible]	96	92	97	94	83	80	76	69
13	[illegible]	[illegible]	96	96	92	82	81	[illegible]	[illegible]
14	[illegible]	[illegible]	96	96	91	84	80	[illegible]	[illegible]
15	[illegible]	[illegible]	95	95	89	83	80	76	71
16	[illegible]	[illegible]	95	94	88	83	79	75	[illegible]
17	[illegible]	85	95	94	88	83	79	76	71
18	[illegible]	93	94	93	88	82	80	75	71
19	[illegible]	94	94	92	88	82	80	75	71
20	[illegible]	93	[illegible]	[illegible]	88	83	79	75	71
21	[illegible]	93	[illegible]	92	88	84	80	76	71
22	[illegible]	92	94	91	88	85	80	77	71
23	[illegible]	92	93	91	88	84	81	76	71
24	[illegible]	[illegible]	93	90	88	84	[illegible]	76	71
25	[illegible]	[illegible]	92	90	88	84	81	76	71
26	[illegible]	91	92	89	88	84	81	76	71
27	[illegible]	91	92	89	88	84	81	76	71
28	[illegible]	91	[illegible]	88	88	84	81	76	71
29	[illegible]	91	[illegible]	88	87	84	81	76	71
30	[illegible]	91	91	88	87	84	81	77	[illegible]
31	[illegible]	91	91	87	87	84	81	77	71
32	[illegible]	91	90	87	86	84	81	77	71
33	[illegible]	91	90	86	86	83	81	77	[illegible]
34	[illegible]	[illegible]	[illegible]	85	84	84	82	[illegible]	[illegible]
35	[illegible]	[illegible]	91	85	85	84	81	77	[illegible]
36	[illegible]	[illegible]	89	84	85	84	81	76	[illegible]
37	[illegible]	91	90	83	86	84	80	76	[illegible]
38	[illegible]	[illegible]	90	87	[illegible]	83	80	77	[illegible]
39	[illegible]	[illegible]	90	[illegible]	[illegible]	83	[illegible]	77	[illegible]
40	[illegible]	[illegible]	90	85	85	[illegible]	81	77	77
41	[illegible]	[illegible]	[illegible]	88	84	82	[illegible]	76	77
42	[illegible]	[illegible]	87	[illegible]	85	80	80	77	[illegible]
43	[illegible]	[illegible]	86	89	85	81	78	75	[illegible]
44	[illegible]	[illegible]	83	87	81	82	78	75	[illegible]
45	[illegible]	[illegible]	84	[illegible]	83	82	78	75	-
46	[illegible]	[illegible]	87	[illegible]	84	[illegible]	[illegible]	76	-
47	[illegible]	[illegible]	89	81	86	82	74	74	-
48	[illegible]	[illegible]	90	83	[illegible]	81	78	-	-
49	[illegible]	-	-	-	-	-	-	-	-
50	[illegible]	-	-	-	-	-	-	-	-

TABLE 2D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 2

DATA POINT N	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, DB, AT 200 FEET FROM SOUND SOURCE — OCTAVE BAND CENTER FREQUENCIES, HZ: 63	125	250	500	1K	2K	4K	8K
1	2.6	-	-	-	-	-	-	-	-
2	5.7	-	-	-	-	-	-	-	-
3	8.8	-	-	-	-	-	-	-	-
4	12.2	110	109	99	89	84	74	-	-
5	15.4	104	108	98	94	88	75	78	-
6	19.5	108	106	94	95	84	77	76	-
7	24.2	107	103	94	96	84	76	75	-
8	28.6	106	101	94	96	84	76	74	-
9	33.4	105	98	96	94	83	74	73	-
10	37.2	103	93	95	92	84	76	73	66
11	41.7	100	90	94	92	85	76	74	67
12	46.0	100	89	93	94	84	76	73	66
13	51.0	97	89	93	94	83	77	73	67
14	55.2	95	89	92	92	83	77	73	67
15	59.9	91	90	93	90	82	78	74	68
16	63.3	91	92	93	90	81	78	74	69
17	66.9	90	93	93	89	82	79	75	69
18	70.6	88	[illegible]	93	89	81	79	76	70
19	74.5	85	95	93	89	81	79	75	70
20	78.5	84	95	93	89	82	79	76	70
21	82.7	84	95	93	87	83	79	76	71
22	86.9	84	95	92	86	83	80	76	72
23	91.0	85	95	92	86	85	79	77	72
24	95.2	83	94	92	87	86	81	77	72
25	99.2	83	94	91	87	85	81	77	72
26	103.2	82	90	91	87	83	80	77	72
27	107.0	81	90	90	88	83	81	77	72
28	110.6	82	90	90	89	83	81	78	73
29	114.1	81	91	89	90	85	81	78	73
30	118.9	82	92	89	88	85	81	79	74
31	123.3	81	90	86	87	84	82	78	74
32	127.3	78	91	84	88	85	81	78	74
33	131.9	80	89	84	86	85	81	78	74
34	135.9	81	89	86	85	82	80	77	72
35	141.1	86	89	88	84	81	80	76	72
36	144.7	85	87	89	85	81	79	76	72
37	147.7	87	86	90	85	81	80	76	72
38	152.5	85	83	89	83	80	77	75	73
39	156.1	88	84	87	81	79	77	74	-
40	160.1	93	84	85	82	78	75	75	-
41	163.7	93	85	82	82	77	76	-	-
42	166.8	90	87	80	82	77	75	-	-
43	169.9	91	86	78	83	74	75	-	-
44	173.0	-	-	-	-	-	-	-	-
45	176.0	-	-	-	-	-	-	-	-

TABLE 3D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 3

DATA POINT NO.	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, dB, AT 200 FEET FROM SOUND SOURCE; OCTAVE BAND CENTER FREQUENCIES, HZ							
		63	125	250	500	1K	2K	4K	8K
[illegible]	[illegible]	-	-	-	-	-	-	-	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	73	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	95	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	95	87	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	95	87	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	95	94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	71.1	[illegible]	95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	93	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	77.1	[illegible]	94	[illegible]	88	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	92	91	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	91	88	89	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	88	89	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	88	89	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	88	[illegible]	88	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	84	[illegible]	[illegible]	[illegible]	[illegible]	74
[illegible]	[illegible]	[illegible]	[illegible]	85	[illegible]	[illegible]	[illegible]	[illegible]	75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75
[illegible]	[illegible]	[illegible]	[illegible]	88	[illegible]	[illegible]	[illegible]	[illegible]	76
[illegible]	[illegible]	[illegible]	[illegible]	91	[illegible]	[illegible]	[illegible]	[illegible]	74
[illegible]	[illegible]	[illegible]	[illegible]	92	[illegible]	[illegible]	[illegible]	[illegible]	74
[illegible]	[illegible]	[illegible]	[illegible]	96	85	[illegible]	[illegible]	[illegible]	75
[illegible]	[illegible]	[illegible]	[illegible]	90	84	[illegible]	[illegible]	[illegible]	75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-
[illegible]	[illegible]		-	-	-	-	-	-	-

TABLE 4D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 4

DATA POINT N	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, DB, AT 200 FEET FROM SOUND SOURCE — OCTAVE BAND CENTER FREQUENCIES, HZ: 63	125	250	500	1K	2K	4K	8K
1	2.1	-	-	-	-	-	-	-	-
2	5.2	-	-	-	-	-	-	-	-
3	8.5	-	-	-	-	-	-	-	-
4	12.0	111	111	104	92	90	77	-	-
5	15.6	110	109	100	96	89	78	73	-
6	19.4	111	108	98	95	84	76	75	-
7	22.8	109	106	96	96	86	77	74	-
8	26.3	108	104	98	95	86	77	74	-
9	30.7	107	101	98	94	84	76	73	
10	34.3	105	98	98	90	84	77	74	[illegible]
11	38.8	103	94	97	89	84	77	74	[illegible]
12	42.6	102	91	94	89	83	77	73	67
13	46.7	99	88	93	92	84	76	73	67
14	50.9	98	88	93	92	83	77	72	[illegible]
15	55.6	95	89	93	91	84	77	73	[illegible]
16	59.1	92	90	94	91	83	79	74	[illegible]
17	63.0	91	92	95	91	83	79	74	[illegible]
18	66.7	90	92	94	90	83	79	74	[illegible]
19	70.8	88	94	94	90	81	79	75	[illegible]
20	75.2	87	94	94	90	81	79	75	[illegible]
21	79.7	85	94	94	89	81	79	76	[illegible]
22	84.2	84	94	94	88	82	80	76	71
23	88.8	83	94	94	88	82	80	76	72
24	93.4	83	94	93	88	83	81	77	[illegible]
25	97.9	83	94	93	88	83	81	77	[illegible]
26	102.1	83	93	92	88	83	81	76	[illegible]
27	106.5	82	90	91	88	84	82	76	[illegible]
28	110.5	82	91	91	88	84	81	77	[illegible]
29	114.7	82	91	89	89	85	81	77	[illegible]
30	117.9	83	91	90	88	85	81	74	[illegible]
31	123.0	83	90	88	88	85	82	77	[illegible]
32	127.2	83	91	88	88	86	81	78	74
33	131.1	83	90	87	87	85	81	78	74
34	135.6	84	90	87	86	85	81	78	73
35	140.5	85	90	88	86	84	80	77	73
36	144.4	85	88	88	86	83	79	77	72
37	147.7	87	87	89	84	82	79	76	72
38	152.4	89	85	89	85	81	78	75	-
39	156.3	91	84	89	84	81	77	76	-
40	160.6	92	84	85	83	79	77	76	-
41	164.3	91	86	83	85	82	79	74	-
42	167.4	91	86	78	81	76	73	-	-
43	170.4	-	-	-	-	-	-	-	-

TABLE 5D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 5

DATA POINT NO.	SOUND SOURCE ANGLE, DEGREES	63	125	250	500	1K	2K	4K	8K
		CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, DB, AT 200 FEET FROM SOUND SOURCE							
		OCTAVE BAND CENTER FREQUENCIES, HZ							
[illegible]	1.8	-	-	-	-	-	-	-	-
[illegible]	4.0	-	-	-	-	-	-	-	-
[illegible]	8.1	-	-	-	-	-	-	-	-
[illegible]	11.6	113	111	100	97	86	82	88	-
[illegible]	14.7	112	109	102	101	84	84	84	-
	18.5	116	105	101	98	87	81	82	-
[illegible]	22.1	108	101	100	97	86	78	79	-
[illegible]	26.8	107	95	99	97	85	78	78	[illegible]
[illegible]	30.3	105	91	99	97	85	80	[illegible]	[illegible]
[illegible]	34.6	100	90	99	97	86	79	[illegible]	[illegible]
[illegible]	39.[illegible]	97	94	99	96	86	79	[illegible]	71
[illegible]	[illegible]	95	95	98	95	87	80	[illegible]	[illegible]
[illegible]	47.3	93	97	97	93	84	80	[illegible]	[illegible]
[illegible]	50.6	93	97	97	93	83	[illegible]	[illegible]	[illegible]
[illegible]	54.3	97	96	96	92	85	81	[illegible]	[illegible]
[illegible]	58.4	85	96	95	90	85	81	[illegible]	71
[illegible]	62.8	85	96	95	90	85	81	[illegible]	71
	67.5	84	95	94	88	86	82	[illegible]	[illegible]
[illegible]	70.1	84	95	93	88	85	82	77	[illegible]
[illegible]	72.5	94	95	93	88	84	83	77	[illegible]
[illegible]	75.1	[illegible]	95	93	88	84	81	77	[illegible]
[illegible]	77.7	[illegible]	95	93	88	84	81	[illegible]	[illegible]
[illegible]	80.4	[illegible]	95	92	88	84	81	77	[illegible]
	83.1	[illegible]	94	92	88	84	81	77	[illegible]
[illegible]	85.4	83	93	91	88	84	81	77	[illegible]
[illegible]	88.6	83	92	91	88	84	81	[illegible]	[illegible]
[illegible]	91.3	82	91	90	88	84	81	[illegible]	[illegible]
[illegible]	94.6	82	91	89	87	84	80	[illegible]	[illegible]
[illegible]	96.7	82	90	89	87	84	80	[illegible]	[illegible]
[illegible]	99.3	82	89	89	87	84	80	[illegible]	[illegible]
[illegible]	101.[illegible]	82	89	88	87	83	80	[illegible]	[illegible]
[illegible]	106.[illegible]	81	88	87	86	83	81	[illegible]	[illegible]
[illegible]	111.6	81	88	86	86	83	81	[illegible]	[illegible]
[illegible]	115.4	82	89	87	86	84	81	71	[illegible]
[illegible]	119.4	82	89	86	86	84	82	78	[illegible]
[illegible]	123.6	83	89	85	86	85	82	[illegible]	[illegible]
[illegible]	[illegible]	83	90	85	86	85	83	[illegible]	[illegible]
[illegible]	[illegible]	83	90	85	86	84	81	[illegible]	[illegible]
[illegible]	[illegible]	84	90	87	85	85	81	74	[illegible]
[illegible]	142.1	85	90	89	86	84	81	74	[illegible]
[illegible]	146.3	87	88	91	86	83	[illegible]	[illegible]	[illegible]
[illegible]	149.7	89	88	92	86	84	81	[illegible]	[illegible]
[illegible]	154.5	91	86	90	85	84	82	78	[illegible]
[illegible]	158.6	92	85	90	87	82	83	[illegible]	-
[illegible]	162.5	93	87	84	85	87	81	81	-
	166.1	92	89	82	86	85	82	83	
[illegible]	169.3	93	91	84	[illegible]	85	83	-	-
	[illegible]	-	-	-	-	-	-	-	-

TABLE 6D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 6

DATA POINT N	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, DB, AT 200 FEET FROM SOUND SOURCE — OCTAVE BAND CENTER FREQUENCIES, HZ: 63	125	250	500	1K	2K	4K	8K
1	2.9	-	-	-	-	-	-	-	-
2	5.9	-	-	-	-	-	-	-	-
3	9.1	-	-	-	-	-	-	-	-
4	12.2	111	110	103	92	88	80	-	-
5	15.5	110	108	100	92	82	76	-	-
6	19.5	110	108	96	94	82	77	77	-
7	24.2	109	107	101	98	87	79	75	-
8	28.7	108	103	100	96	85	78	75	-
9	33.4	107	99	100	93	83	77	74	-
10	37.2	106	94	99	91	84	77	74	-
11	41.7	104	89	97	90	83	77	73	-
12	45.9	103	90	96	92	83	76	73	67
13	50.9	100	89	95	92	83	76	73	66
14	55.1	98	89	94	92	84	76	73	66
15	59.7	94	91	94	89	81	77	73	66
16	63.0	93	93	95	88	81	77	74	67
17	66.5	91	93	94	87	81	78	75	67
18	70.2	88	94	94	86	80	79	74	64
19	74.1	87	95	94	86	81	79	75	69
20	78.1	85	95	94	86	81	79	76	70
21	82.1	84	95	94	87	82	79	76	70
22	86.3	84	95	94	87	82	79	75	71
23	90.4	83	95	93	87	83	79	76	71
24	94.5	83	94	93	86	84	80	76	71
25	98.5	83	94	92	88	84	80	78	72
26	102.4	83	93	91	88	84	82	78	72
27	106.2	83	93	90	89	85	82	78	72
28	109.8	83	92	89	89	85	82	78	73
29	113.2	83	90	88	89	86	82	79	72
30	118.1	84	90	88	89	86	82	78	73
31	122.4	83	90	87	87	85	81	79	73
32	126.4	84	90	87	87	85	81	79	73
33	131.1	84	89	86	87	85	81	79	73
34	135.2	85	90	87	85	83	81	78	73
35	139.6	85	89	88	84	[illegible]	80	79	73
36	143.3	86	88	88	83	82	80	77	73
37	146.4	87	86	90	84	83	79	77	73
38	151.0	89	84	89	85	82	77	76	-
39	154.9	90	82	87	83	81	76	75	-
40	157.9	91	82	85	83	79	76	75	-
41	161.3	92	84	83	81	78	76	77	-
42	164.5	92	86	92	82	77	76	-	-
43	167.7	90	88	84	84	80	79	-	-
44	170.9	-	-	-	-	-	-	-	-
45	173.9	-	-	-	-	-	-	-	-

TABLE 7D

Calculated Sound Pressure Levels at a Constant Distance of 200 Feet and Corresponding Angles for Flight No. 7

DATA POINT NO.	SOUND SOURCE ANGLE, DEGREES	CALCULATED OCTAVE BAND SOUND PRESSURE LEVELS, DB, AT 200 FEET FROM SOUND SOURCE OCTAVE BAND CENTER FREQUENCIES, HZ 63	125	250	500	1K	2K	4K	8K
1	3.5	-	-	-	-	-	-	-	-
2	6.[illegible]		-	-	-	-	-	-	-
3	9.[illegible]	-	-	-	-	-	-	-	-
4	12.[illegible]	[illegible]	107	96	97	85	85	-	-
5	16.1	111	107	101	97	85	82	-	-
6	19.[illegible]	[illegible]	102	101	95	85	79	90	-
7	22.[illegible]	[illegible]	98	100	93	84	78	86	-
8	27.[illegible]	102	92	98	93	83	79	82	-
9	30.6	99	91	96	93	83	79	80	-
10	35.[illegible]	[illegible]	91	95	93	83	79	78	-
11	39.[illegible]	91	94	95	92	83	79	78	-
12	43.[illegible]	90	95	95	91	82	79	77	-
13	46.[illegible]	87	95	95	91	82	79	77	-
14	51.[illegible]	85	97	95	89	82	79	76	-
15	55.[illegible]	83	96	94	88	82	80	76	-
16	60.[illegible]	82	96	94	88	81	80	76	-
17	64.[illegible]	81	95	92	88	82	80	77	-
18	69.[illegible]	81	94	92	87	83	79	76	-
19	73.[illegible]	81	94	91	87	82	80	77	-
20	77.[illegible]	81	93	91	86	82	80	76	-
21	81.[illegible]	81	92	90	86	82	79	76	-
22	86.[illegible]	80	90	89	86	82	79	76	-
23	90.[illegible]	[illegible]	89	88	86	82	79	76	-
24	94.4	80	89	88	86	82	79	76	-
25	98.5	80	88	88	86	82	79	76	-
26	102.[illegible]	80	87	87	85	81	80	76	-
27	106.2	80	87	86	85	81	80	77	-
28	111.0	80	87	85	85	82	79	76	-
29	115.[illegible]	80	87	84	85	82	80	77	-
30	119.[illegible]	81	87	85	85	81	80	77	-
31	124.4	81	87	83	84	82	80	77	-
32	128.6	82	88	83	84	81	79	77	-
33	132.3	83	87	83	83	81	79	77	-
34	135.7	84	88	84	84	82	79	78	-
35	140.[illegible]	85	87	85	83	82	79	78	-
36	144.9	86	86	87	83	81	79	78	-
37	149.[illegible]	88	85	88	82	81	79	80	-
38	151.8	89	84	88	84	81	79	81	-
39	155.9	90	83	88	84	81	79	84	-
40	159.[illegible]	92	84	87	83	82	81	-	-
41	162.[illegible]	91	85	87	84	82	82	-	-
42	165.[illegible]	91	86	80	81	77	-	-	-
43	169.6	92	88	76	80	-	-	-	-
44	172.1	-	-	-	-	-	-	-	-

APPENDIX E

POLAR PLOTS OF THE SOUND PRESSURE LEVELS IN EACH OCTAVE BAND FOR FLIGHTS 1 THROUGH 7

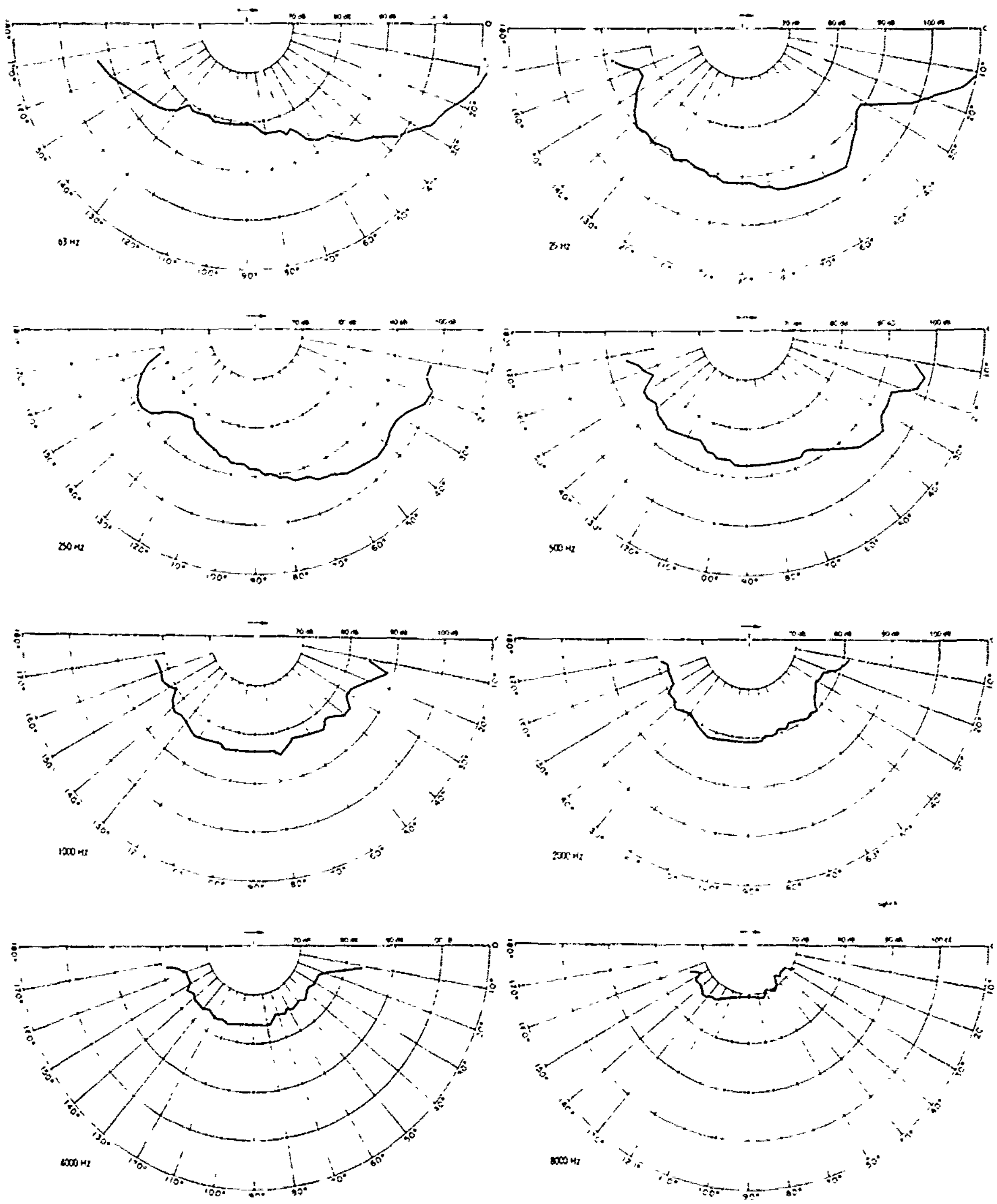

Fig. 1E. Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 1.

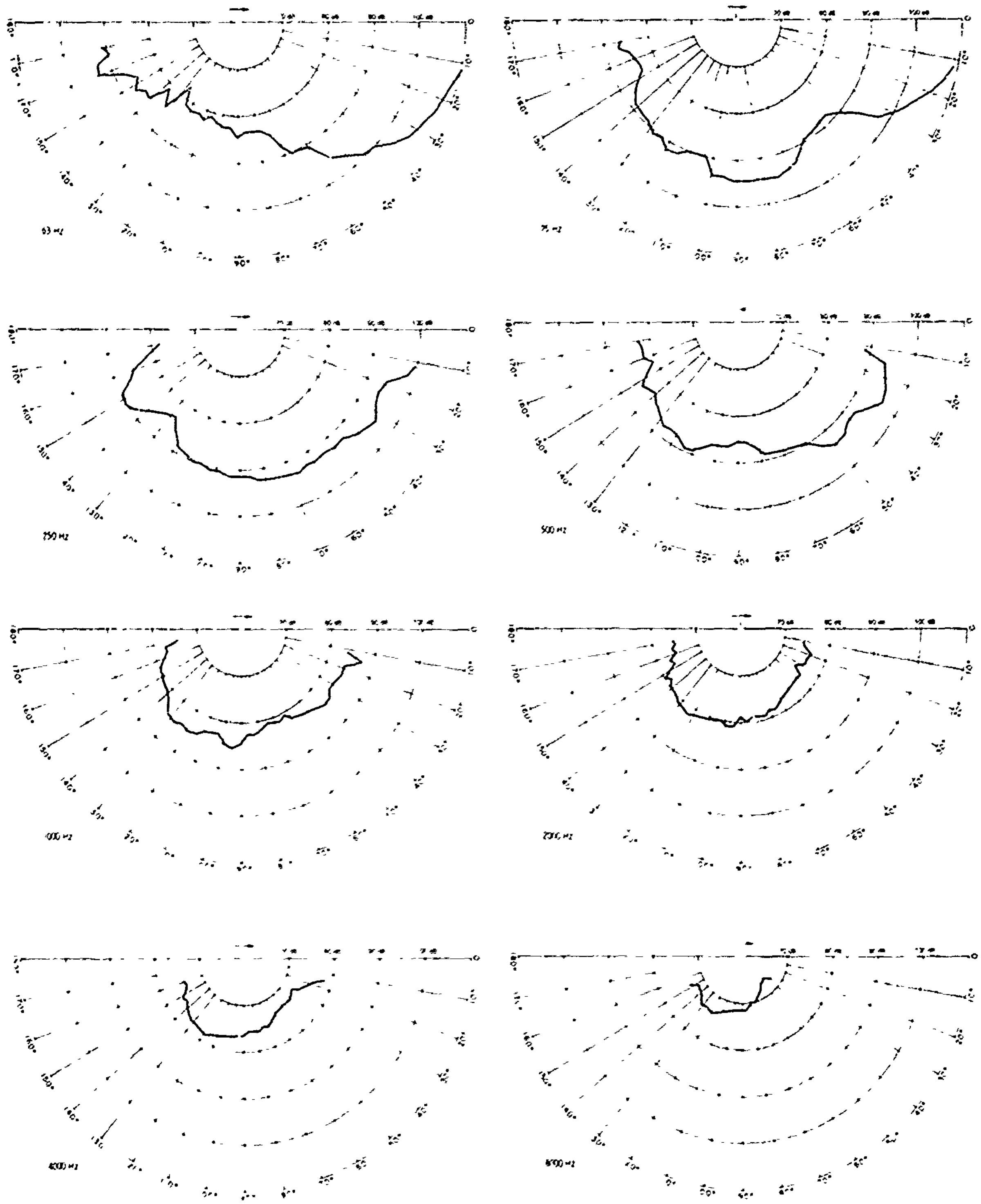

Fig 2E. Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 2.

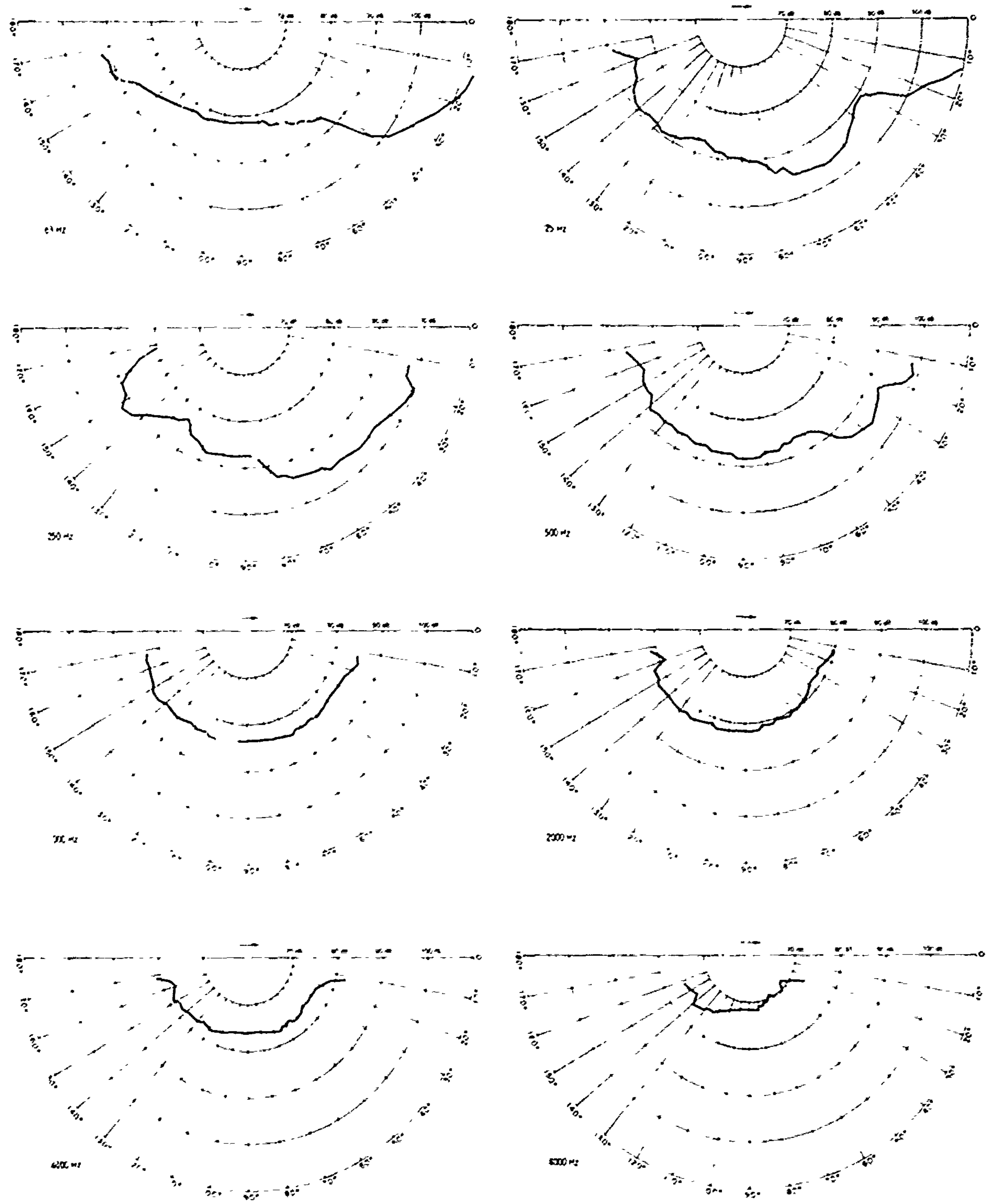

Fig. 3E. Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 3.

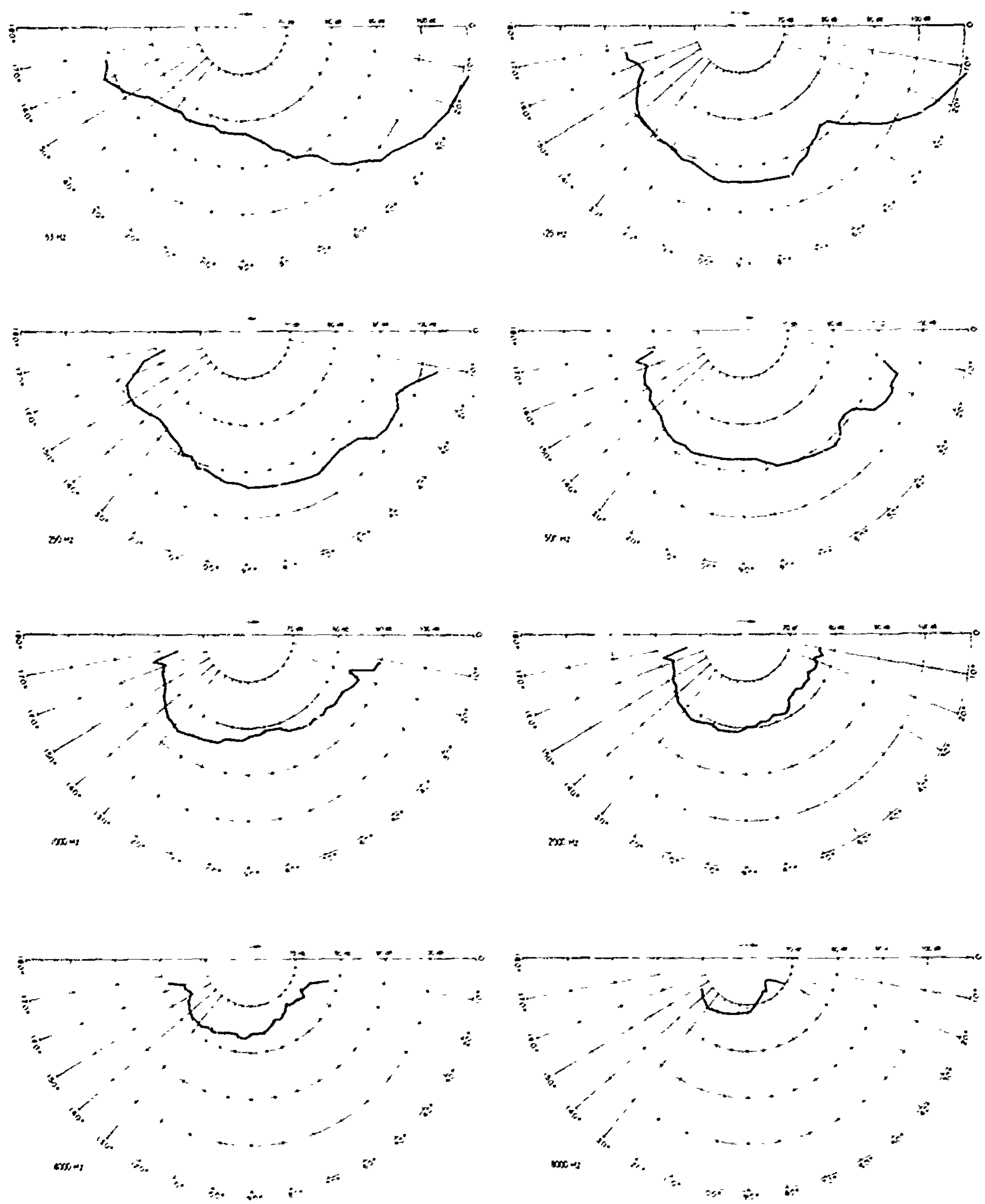

Fig. 4E Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 4.

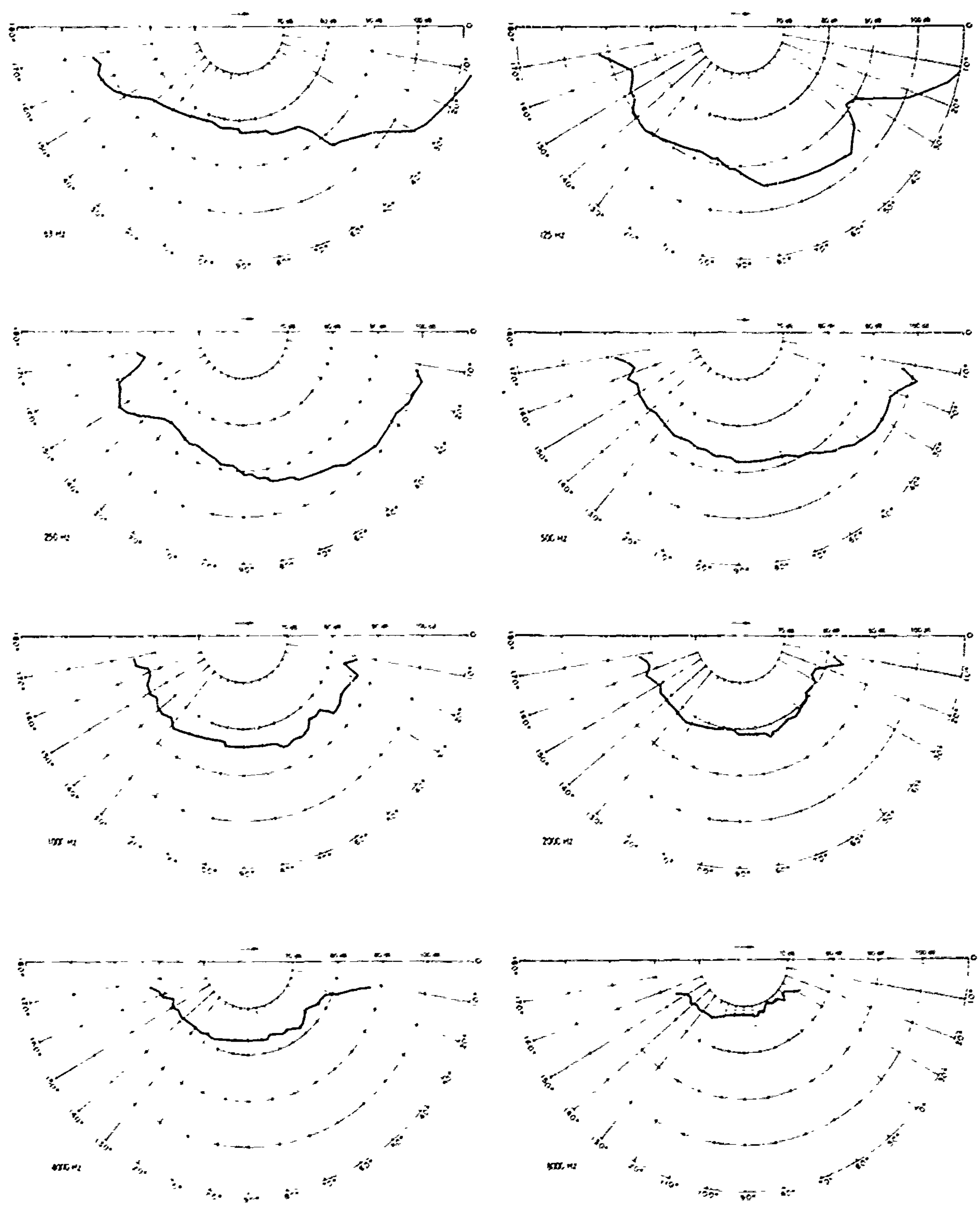

Fig. 5E. Octave band sound pressure levels at 200 feet from a moving helicopter--flight number 5.

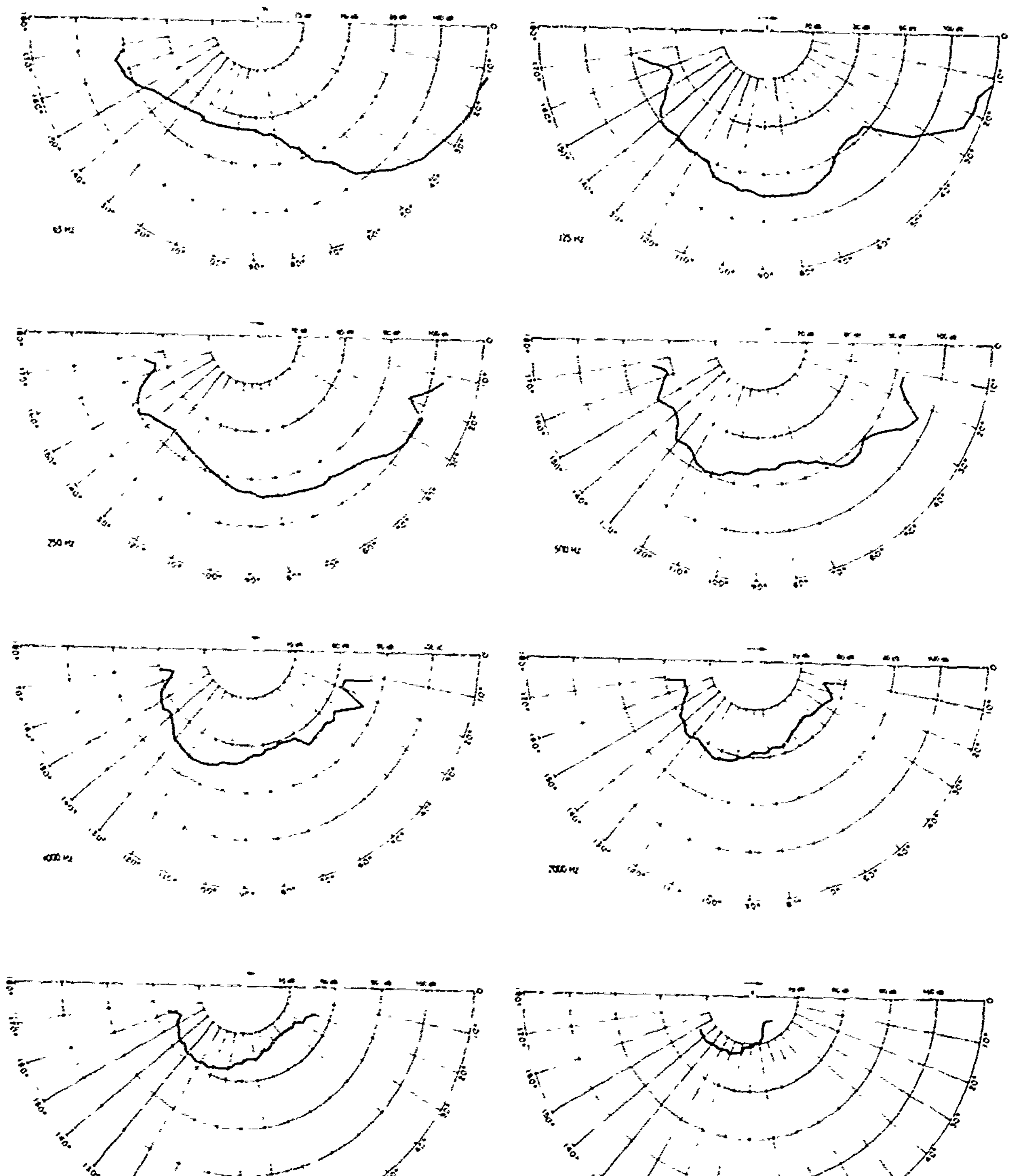

Fig. 6E. Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 6.

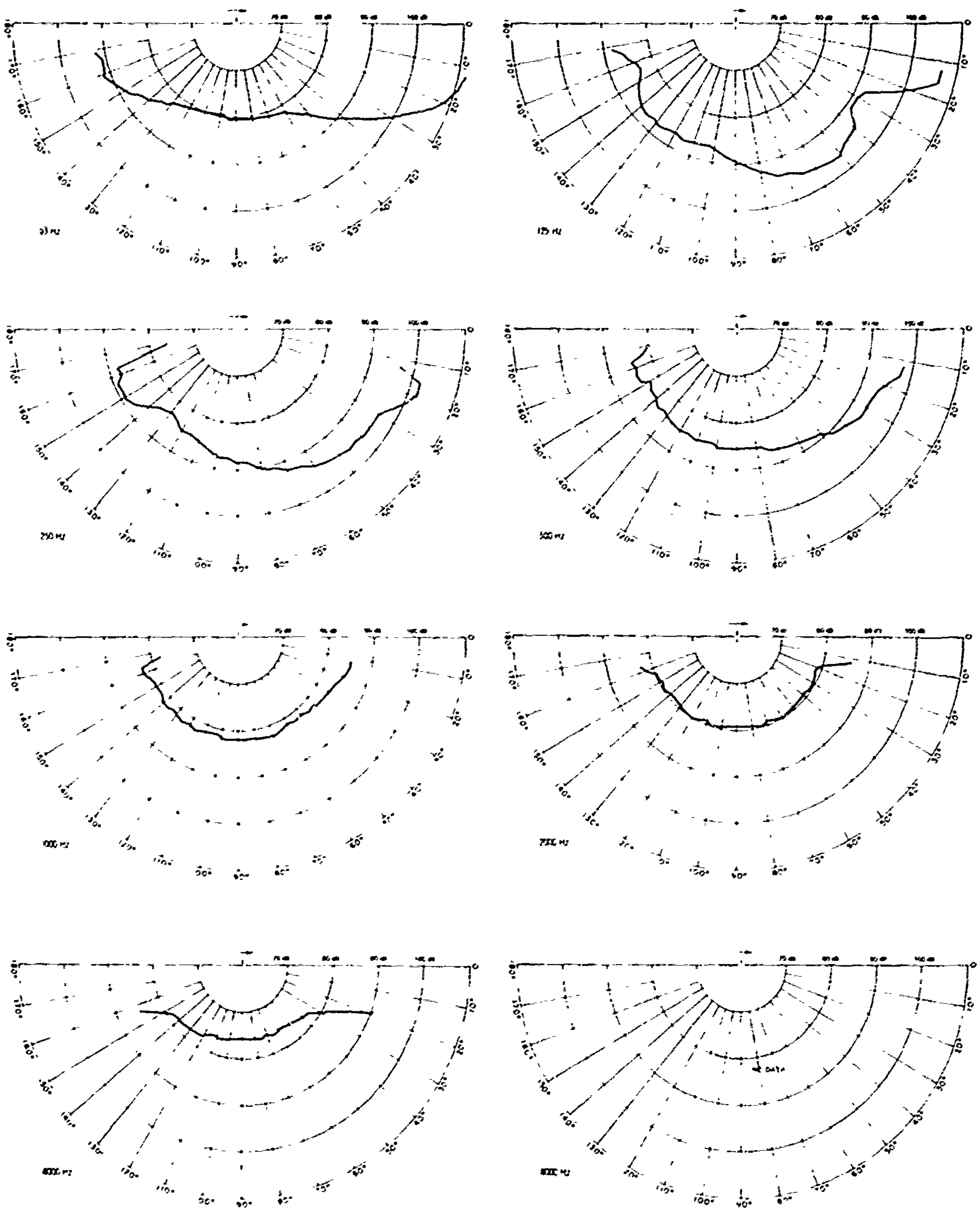

Fig. 7E. Octave band sound pressure levels at 200 feet from a moving helicopter-flight number 7.